FIRE, HABITATS, AND WILDLIFE

Final report submitted to USDA Forest Service
Coconino National Forest

By David R. Patton and Janet Gordon

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INTRODUCTION

Fire is a natural or human-caused event that can bring about major changes in the attributes of wildlife habitat--plant density and species composition. The effects of fire on wildlife species and habitats have to be examined in detail for each animal using an area and each plant that an animal uses for food or each vegetation type for cover.

The major impact of fire on wildlife is not the short-term direct effects but the long-term indirect effects from alterations in the amounts and types of food and cover for a variety of animal species. These indirect effects can be either beneficial or detrimental depending on individual circumstances; therefore, fire in a controlled state is a paradox that has to be understood in detail before it can be used to create a particular habitat for wildlife.

The objective of this manuscript is to bring together information that managers can use when considering fire as a management tool in habitat occupied by endangered, threatened, and other species. There was no intent to provide information on prescribed fire techniques or to present an overview of fire history in specific vegetation types. This material can be found in other publications (Covington and Moore 1994, USDA 1994).

The information on the effects of fire on wildlife habitats and species all comes from scientific literature and is based on results from research. As with most research there can be conflicting or uncertain evidence about a subject and fire and

its effects on wildlife is no exception. While the information presented in this report can be documented from the literature, in many cases the relationships are intuitive or self-evident from experience. The information presented herein must be viewed as baseline and can only improve as results from research continues to be evaluated for management purposes.

The information presented is only as good as the source of the data and for fire and wildlife this tends to be of moderate accuracy. In most cases the information is sufficiently broad so that some interpretation may be needed for local management situations.

EFFECTS OF FIRE ON WILDLIFE SPECIES

The indirect effects of fire on wildlife, though difficult to quantify, are substantially greater for some species due to the loss of habitat which leads to starvation, predation, or decimation by weather. However for many species, such as deer and elk, fire has the opposite effect primarily because of a rapid increase of food for 1-3 years following a burn (Cook 1959; Lawrence 1966).

Burned areas often support more diverse animal populations than comparable unburned sites due to increased habitat diversity (Beck and Vogl 1972, Wirtz 1977, Bell and Studinski 1972); therefore, using fire to create habitat diversity and edge is a viable management alternative. The importance of edge as wildlife habitat is well documented (Thomas 1979, Dasmann 1966).

The cost of creating small openings with controlled burning in shrubby habitat or dense tree stands is lower than the cost of other means of manipulation vegetation (Dasmann et al, 1967). Burning to increase edge has the added advantage of providing a high-quality food base. For example, for two growing seasons following fire, protein and phosphorus content of new browse growth increased (Bendell 1974, Lay 1967, Miller 1963).

Fire also affects special features of wildlife habitat. Fire-killed snags and downed materials are important cover and food storage sites for small mammals, birds, and insects. Bats roost under bark of snags, and rodents are often associated with dead woody materials (Baker 1974).

Raspberry and currant shrubs that invade burns at high elevations offer seasonal berry crops and are especially sought after by bears. Other omnivores and carnivores are attracted to burns by increased plant diversity and associated small mammal populations (Gruell 1980). There is an indication that numbers of animal parasites may be lower on burned habitat (Bendell 1974, Lyon et al. 1978). In addition snow melts more rapidly on burned than on unburned sites, thereby offering valuable early spring forage for elk and deer (Singer 1979, Bendell 1974).

The direct impact of fire on an animal is a function of the animal's size and mobility, and the extent, intensity, and speed of the fire. Adult deer and elk commonly avoid fire because they can easily move away from the advancing flames but young animals may not be so fortunate. Chipmunks, shrews, woodrats, and mice are generally reluctant to leave burning woodpiles and grass stands and are probably killed directly (Bendell 1974). However, species living underground can survive intense heat due to the great decrease in temperature below the surface (Howard, Fenner, and Childs 1959).

One direct effect of fire on wildlife is death by burning or suffocation, particularly in the case of small mammals (Lawrence 1966). The air temperature at which animals are killed is 63°C (145°F) (Howard, Fenner, and Childs 1959). Direct mortality has been documented in animals as varied as birds and voles (Bock and Lynch 1970; Hakala et al. 1971) deer, woodrats and rabbits (Chew, Butterworth, and Grechman 1958; Buech et al. 1977). In most

cases, death by burning is rare except for large, hot fires (Vogl 1977). In general the loss of vertebrates directly to the effects of fire is negligible.

Starvation of animals following fire results from loss of vegetation. Species of limited mobility (home range) are most susceptible. Even when starvation does not result in death, an animal's ability to reproduce is frequently impacted when food is limited because nutrients are used for body maintenance rather than reproduction. Following a fire in northern California, Chipmunks were found to have lost as much as 20 percent of their body weight (Taylor 1995).

Predation on small mammals subsequent to fire is generally increased since a survivor has to search for food at greater distances from cover. Fire may reduce vegetation exposing animals in open areas and increasing their vulnerability to predators. It is not uncommon to see hawks and owls in recently burned areas presumably because small mammals are easier to hunt in areas where there is little or no vegetation. In one study in northern California, radio-collared northern spotted owls spent considerable time in burned-over areas. This activity was assumed to be due to easy capture of prey (Taylor 1995).

Decimation of animals from weather after fire results from a loss of cover that provided protection from wind, water, and heat. Although cover may still exist in the burned area, cover

for nesting, feeding, resting, and loafing may be too thin to protect both adults and young from the elements.

Amphibians and Reptiles (Appendix A)

No information is available in the current literature that describes the response of any southwestern amphibian or reptile to fire or to fire-induced habitat change. Amphibians have been observed to avoid injury or death during a marsh fire in the Southeast by hiding in the water and wet mud until the flames pass (Kimarek 1969). Reptiles may be able to escape due to their ability to detect fire with heat-sensing pits they use in locating prey (Komarek 1969).

In post-fire habitat, reptiles may benefit from the increased warmth. In chaparral vegetation, lizards used charred vegetation for perching sites. Dark-colored species that blended into the blackened background used the charred vegetation most frequently (Lillywhite 1977) and snakes and lizards used burned snags and root systems as dens (Baker 1974).

Birds (Appendix B)

Responses of birds to fire and other disturbance factors have been documented better than those of the other vertebrate groups. Because birds are highly mobile, they are often the first group to colonize a disturbed site. Some birds react to fire itself. This response appears to be related to the availability of prey species such as insects, small birds, and

mammals (Handley 1969, Komarek 1969, Clark 1935). Birds are most vulnerable during nesting and fledging periods. Fire devastates ground-nesting birds not only because it destroys nests, but also because it removes protective cover, and may eliminate insects used for food (Daubenmire 1968).

Turkeys and quail are attracted to very recent burns by increased insect availability (Stoddard 1963, Komarek 1969, Wolfe 1973). Woodpecker populations may increase rapidly in response to wood boring insect populations that quickly attack fire-injured trees (Blackford 1955, Heinselman 1973). Lowe et al. (1978) provided a summary of avian response to fire in ponderosa pine forests of northern Arizona:

> Total bird population increased in the first two years after fire then decreased to levels lower than populations of unburned sites. Timber gleaning birds decreased dramatically after trees were killed and remained depressed for a 20-year observation period. Tree foliage searching birds increased immediately after fire, then dramatically decreased in older stages. Flycatchers reach peak population levels on 7-year old burns. Timber drilling birds increased in response to increases in wood boring insects in fire killed trees. Ground and brush foragers increased dramatically immediately following fires and declined with canopy cover increase.

Numbers of ground feeders and flycatchers increased after forest thinning and slash burning at Sequoia National Park (Kilgore 1971). Ground feeders and flycatchers increased and foliage-gleaning species decreased after fire in previously dense lodgepole pine forests (Roppe and Hein 1978). Foliage insectivores appear to become displaced by a burn. This may be a result of the consumption of herbivorous insects by the fire (Spires et al. 1982). In on case there were fewer foliage

insectivores on burned than on unburned sites two years after fire (Blake 1982).

Woodpeckers and other insectivores such as warblers frequently increase on burns where their insect prey base increases in response to fire-injured trees (Stoddard 1963, Heinselman 1973, Hagar 1960, Blackford 1955). Because woodpeckers are primary cavity nesters, their activity in fire-killed snags is beneficial for secondary cavity nesters, such as bluebirds (Taylor and Barmore 1980). In grasslands and chaparral, increased forb composition after fire is beneficial to herbivores and seed eaters (Bock et al. 1976, Lawrence 1966, Wirtz 1977). In shrub-grass complexes, bird diversity and abundance is enhanced if shrub cover and nesting sites are interspersed with open grassy areas (Baldwin 1968, Pulliam and Mills 1977). These open grassy areas may be created by fire.

Beneficial effects of fire have been documented for water fowl. Marsh burning during dry periods opens up reed-choked waters and may result in deeper pools if roots of aquatic plants are destroyed. Decreases in reeds and cattails are followed by increases in more diverse emergent plant communities, including valuable forage plants. Waterfowl benefit from increased forage and by edge stimulated by decreased reed cover (Givens 1962, Miller 1963, Schlichtemeier 1967, Ward 1968, Kirsch and Kruse 1973, Vogl 1967).

Fishes

The impacts of fire on fish are the result of physical and chemical changes caused by vegetation removal in the surrounding watershed. Removal of stream bank vegetation commonly increases water temperatures leading to corresponding changes in fish species composition (Lyon et al. 1978; Swanston 1980). A change in water temperature may also affect fish distribution patterns (Koya 1977). With increased temperatures, water oxygen supply will decrease as faunal oxygen demand increases (Swanston 1980, Lyon et al. 1978). Wild fire generally results in an increase in erosion leading to increased sedimentation, killing fry or destroying eggs (Swanston 1980).

Nutrient cycles may be altered after fires. Post-burn stream eutrophication that may enhance the growth of algae and emergent plants is a function of precipitation and watershed soil exchange capacities (Swanston 1980). Several studies have documented post-fire changes in nutrient cycles in various vegetation types (DeByle 1976, Stark 1976, Longstreth and Patten 1975, Viro 1974, Whysong and Heisler 1978). The amount of change is related to local climate, vegetation, and soil characteristics, as well as fire intensity, size, and season. The most consistent effect of fire is the loss of watershed nitrogen. Changes in stream nutrient levels may be beneficial to some populations when food bases are increased (Lichtkoppler and Boyd 1977).

Fire-induced changes in physical characteristics also depend on diverse environmental interactions. Ralston and Hatchell (1971) suggest that infiltration capacity, structural aggregate, micro- and macro-pore space, and incorporated organic matter may be increased, decreased, or unaffected by burning. Burning and other forms of vegetation manipulation have been used in the Southwest to increase water yields, especially in the chaparral vegetation type (Zwolinski and Ehrenreich 1967, Arnold 1963). The effects of these increased water yields on fish species have not been documented.

Mammals (Appendix C)

Deer and elk are apparently attracted to recently burned habitat by an increase in forage quantity and quality (Kilgore 1973, Boeker et al. 1972, McCulloch 1969a, Dills 1970, Hallisey and Wood 1976). Leopold (1923) observed deer eating ash the day after a fire in coniferous forest and elk ate the bark of burned lodgepole pine after the Yellowstone fire in 1988 (White and Garrott 1988). Ash contains concentrated amounts of minerals and thus provides a form of dietary supplement (Viro 1974).

Most small mammals escape fires by hiding in burrows or rock crevices (Howard et al. 1959, Heinselman 1973). An intense fire does not eliminate rodents, but it does sharply reduce the numbers and diversity of the small mammal population for a year following the fire (Halvorson 1981). Mature cotton rats have been observed relocated their young during a fire (Komarek 1969).

Thus, even some small mammals of limited mobility are capable of avoiding fire.

Because rodents can rapidly repopulate forest types after fire, it is generally an ineffective control measure of unwanted species (Ahlgren 1966, Komarek 1963). Daubenmire (1968) reported that grassland fires that temporarily remove food and cover may be detrimental to small rodents. Even so, repopulation of such areas is reported to be nearly complete within 6 months (Cool 1959). Mice and rodents often increase after fire in response to increased availability of forb seeds and insects (Lyon et al. 1978).

WILDLIFE-FIRE RESPONSE CLASSIFICATION

Wildlife species can be categorized by their response to fire: fire-intolerant, fire-impervious, fire-adapted, or fire-dependent (Walter 1977). These categories are approximate because the information used to include each species in a category is not exact. As a result a few species may be listed in more than one category.

Fire-intolerant species decrease in abundance after fire and are present only in areas characterized by very low fire frequency and intensity. Characteristic species include the hermit thrush, spotted owl, and bushtit, which are closely associated with dense, shrubby habitat and closed canopy forests. These birds prefer a dense nesting and foraging cover and do not use large fire-opened habitat.

Common Name	Lifeform
Ash-throated flycatcher	bi
Bewick's wren	bi
Black-capped chickadee	bi
Black-throated gray warbler	bi
Blue-gray gnatcatcher	bi
Brewer's sparrow	bi
Brown creeper	bi
Burrowing owl (?)	bi
Bushtit	bi
Cassin's finch	bi
Chipping sparrow	bi
Elf owl	bi
Golden-crowned kinglet	bi
Grace's warbler	bi
Grasshopper sparrow	bi
Great horned owl	bi
Hammond's flycatcher	bi
Hermit thrush	bi
Hermit warbler	bi
Mountain chickadee	bi
Northern goshawk (?)	bi

Northern harrier	bi
Pine siskin	bi
Purple finch	bi
Pygmy nuthatch	bi
Red crossbill	bi
Red-breasted nuthatch	bi
Red-faced warbler	bi
Ruby-crowned kinglet	bi
Rufous-sided towhee	bi
Scott's oriole	bi
Scrub jay	bi
Sharp-shinned hawk (?)	bi
Solitary vireo	bi
Spotted owl	bi
Virginia's warbler	bi
Western flycatcher	bi
Western tanager	bi
White-crowned sparrow	bi
White-throated sparrow	bi
Yellow warbler	bi
Yellow-rumped warbler	bi
Arizona pocket mouse	ma
Bailey's pocket mouse	ma
Cactus mouse	ma
Gray-collared chipmunk	ma
Marten	ma
Red squirrel	ma
White-footed mouse	ma

Fire-impervious species are unaffected by burning. Bendell (1974) suggests that most species neither increase nor decrease because of fire. Wildlife species whose niche spans multiple successional and climax community types may be expected to show the highest flexibility in response to fire.

Common Name	Lifeform
American crow	bi
American robin	bi
Black vulture	bi
Black-billed magpie	bi
Blue grosbeak	bi
Blue jay	bi
Blue-winged teal	bi

Brown thrasher	bi
Brown-headed cowbird	bi
Canada goose	bi
Cedar waxwing	bi
Chestnut-collared longspur	bi
Clark's nutcracker	bi
Cliff swallow	bi
Common ground-dove	bi
Common raven	bi
Common snipe	bi
Eastern kingbird	bi
European starling	bi
Gadwall	bi
Great blue heron	bi
Great-tailed grackle	bi
Greater roadrunner	bi
Horned lark	bi
Lark bunting	bi
Loggerhead shrike	bi
MacGillivray's warbler	bi
Mallard	bi
Mourning dove	bi
Northern cardinal	bi
Northern flicker	bi
Northern mockingbird	bi
Northern pintail	bi
Orchard oriole	bi
Red-winged blackbird	bi
Snowy egret	bi
Song sparrow	bi
Steller's jay	bi
Summer tanager	bi
Townsend's solitaire	bi
Turkey vulture	bi
Eastern cottontail	ma
Pronghorn	ma

<u>Fire-adapted species</u> are associated with habitat that is characterized by recurring fires of various intensities. These species, however, are not dependent on fire-influenced habitat. Fire-adapted wildlife include species that use both dense canopy areas and openings; such as the sharp-shinned and marsh hawks. These birds benefit by increased hunting success on

recent burns, but generally depend on unburned habitat for nesting sites.

Common Name	Lifeform
Acorn woodpecker	bi
American kestrel	bi
American robin	bi
Black-chinned sparrow	bi
Black-headed grosbeak	bi
Blue grosbeak	bi
Blue-winged teal	bi
Brewer's sparrow	bi
Canada goose	bi
Cassin's kingbird	bi
Clark's nutcracker	bi
Cliff swallow	bi
Common nighthawk	bi
Common poorwill	bi
Cooper's hawk	bi
Curve-billed thrasher	bi
Dark-eyed junco	bi
Downy woodpecker	bi
Eastern bluebird	bi
Eastern meadowlark	bi
Fox sparrow	bi
Gadwall	bi
Gambel's quail	bi
Greater roadrunner	bi
Green-tailed towhee	bi
Hairy woodpecker	bi
House wren	bi
Killdeer	bi
Lark sparrow	bi
Lazuli bunting	bi
Mallard	bi
Montezuma quail	bi
Mountain bluebird	bi
Northern flicker	bi
Northern goshawk	bi
Northern harrier	bi
Northern pintail	bi
Purple martin	bi
Rufous-sided towhee	bi
Savannah sparrow	bi
Scaled quail	bi
Snowy egret	bi
Three-toed woodpecker	bi
Tree swallow	bi
Vaux's swift	bi

Vesper sparrow	bi
Violet-green swallow	bi
Western bluebird	bi
Western kingbird	bi
Western meadowlark	bi
Western screech-owl	bi
Western wood-pewee	bi
Wild turkey	bi
Williamson's sapsucker	bi
Winter wren	bi
Yellow-bellied sapsucker	bi
Arizona cotton rat	ma
Badger	ma
Beaver	ma
Bison	ma
Bobcat	ma
Coyote	ma
Deer mouse	ma
Meadow vole	ma
Merriam's kangaroo rat	ma
Mexican gray wolf	ma
Mule deer	ma
Muskrat	ma
Nuttall's cottontail	ma
Pinyon mouse	ma
Red fox	ma
Rocky Mountain bighorn sheep	ma
Thirteen-lined ground squirrel	ma
Western harvest mouse	ma
White-tailed antelope squirrel	ma
White-tailed deer	ma
Green rat snake	re
Western diamondback rattlesnake	re

Fire-dependent species are associated with fire-dependent and fire-adapted plant communities. When fire frequency decreases, these plant communities shift to fire-neutral or fire-intolerant types, and fire-dependent wildlife species are unable to persist. Michigan's kirtland warbler is an example of a fire-dependent species. This bird depends on an early successional stage of pine forest for nesting cover (Line 1964).

Common Name	Lifeform
Blue grouse	bi
House wren	bi
Lesser prairie-chicken	bi
Mourning dove	bi
Northern bobwhite	bi
Sandhill crane	bi
Wild turkey	bi
American elk	ma
Beaver	ma
Mule deer	ma
White-tailed deer	ma

FIRE, PLANTS, AND PLANT COMMUNITIES

The amount of damage living plants suffer from fire is related to type of plant, time of year, stage of growth, age, and physical condition. Injury to living tissue in a plant at a given time of year is also related to intensity and duration of the fire. The lethal temperature for the shoot tissues of land plants is approximately 60° C (Daubenmire 1968). For more susceptible species, this threshold may be as low as 45° C, whereas more tolerant species such as cactus endure significantly higher temperatures. These values have limited usefulness because heat damage to plant tissue is also a function of exposure time. In addition, the temperature of a tissue before burning influences the amount of time and heat necessary to cause injury. Research indicates some seeds may endure 90° C for 40 seconds (Daubenmire 1968). The higher the seed's moisture content, the more susceptible it is to heat injury.

Tree trunks generally are more resistant to fire damage than are other plant forms. Thick-barked trees have greater fire tolerance because the cambium is insulated. Injury to ponderosa pine (Pinus ponderosa) from ground fires is generally confined to scorch of bark and lower branches because of this adaptation. Fire-scarred growth rings are evidence that bark of ponderosa pine is effective in protecting the major portion of the cambium from fire damage (Biswell 1973).

Some plants are not resistant to burning, yet they are able to persist in burned areas because of fire recovery mechanisms.

Such mechanisms include root and crown sprouting, and soil-stored seed banks that germinate after fire scarification (Keely 1977, Hanes and Jones 1966). However, when fire-free intervals are shorter than the time needed by seedlings to mature, even adapted species may be eliminated from the community (Wright 1974a, Cattelino et al. 1979).

Herbaceous plants, which are the most susceptible to complete combustion, often increase dramatically after fire. This is because most herbaceous plants, including perennial species, mature and produce seed within one or two seasons after germination and establishment. In addition, herbaceous pioneer species are disturbance-adapted, exhibiting competitive features such as rapid phenology, copious production of long-lived seed, rapid growth potential, efficient resource capture, and stress-induced dormancy (Grime 1979). In several Rocky Mountain forests, the post-fire presence of plant species that were destroyed or damaged by fire is a result of underground propagules and seed banks (Lyon and Stickney 1976).

PLANT ADAPTIVE STRATEGIES

Classification of plants by growth forms, life histories, and survival strategies has a direct application to fire ecology. Any plant species of interest may be ranked as competitive, stress-tolerant, or ruderal by determining characteristics of the plant's morphology, life history and physiology.

Competitors are plants that are best adapted to resource capture in non-limiting situations, and typically exhibit rapid growth. Stress-tolerant plants have adapted to environmental constraints. These species are characterized by slow growth and stress-resistant features such as waxy leaves, irregular opportunistic fruit set, or chemical herbivore inhibitors. Mechanisms such as these are not valuable in the competitor's non-limiting environment. Ruderal plant species are those that avoid stress and competitions by rapid phenology and long dormant periods as seeds. Ruderals are highly adapted to disturbance because of the copious and rapid seed production.

Survival mechanisms and life form classifications are attempts to arrange plants into functional groups. When plants in a community have been identified according to these fire response classifications, the reactions of the community are more predictable.

There are four possible fire response classifications (Appendix D). First, <u>fire-resistant</u> species are plants that are seldom killed by moderate fires. These plants are mostly trees with large, relatively inflammable stems. The more flammable

leaves and branches are located predominately on the upper stem, well removed from contact with ground fuels. Mature ponderosa pine and honey mesquite (Prosopis glandulsa) are examples (Weaver 1967, Schubert 1974, Wright et al 1976).

Fire-tolerant species are shrubs, small trees, grasses, and forbs that sprout from the root and crown after being top-killed. Fire-tolerant species are eliminated when frequent fires eventually deplete carbohydrate levels below minimums necessary for growth and flowering (Komarek 1976, Wright 1974a). Fire kill of tolerant shrubs is also related to plant size and age. Smaller or younger plants have lower fire-tolerance potential (Cable 1973).

Fire-resistant trees may only be fire-tolerant when young. Juvenile alligator junipers (Juniperus deppeana) and mesquites are killed by repeated fires (Johnson et al. 1962, Cable 1973). Aspen (Populus tremuloides), willow (Salix spp.), oak (Quercus spp.), and some junipers (Juniperus spp.) may be fire-tolerant shrubs that sprout readily after fire (Carmichael et al. 1978, Kittams 1973).

Many perennial grasses are fire-tolerant. Buffalo grass (Buchloe dactyloides), blue grama (Bouteloua gracilis), and sand dropseed (Sporobolus cryptandrus) are unaffected by fire, while vine mesquite (Panicum obtusum), Arizona cottontop (Trichachne californica), little bluestem (Schizachyrium scoparium), and plains bristlegrass (Setaria macrostachya) increase after fire (Wright 1974b). The response of perennial grasses and forbs to

fire is positively correlated with rainfall. When moisture is not limiting, fire may result in increased flowering and seed production (Biswell and Lemon 1944, Curtis and Partch 1950). Grasses decrease significantly after fire in drought years. Cholla and prickly pear cacti (Opuntia spp.) are tolerant of low intensity fires. The remarkable sprouting capabilities of Opuntia stems may result in a post-fire increase in numbers (Buntin et al. 1980).

Fire-intolerant plants are highly flammable, and are generally killed by fire. Two types of fire-intolerant plants exist, those that increase after fire and those that decrease. Plants that are destroyed by fire and do not re-establish are fire-intolerant decreasers. Engelmann spruce (Picea englemannii), white fir (Abies concolor), and pinyon pine (Pinus edulis) are trees that decrease following fire (Gabeck and Mutch 1973, Wellner 1970). Grasses that decrease after fire include slimstem muhly (Muhlenbergia filiculmis), ring muhly (Muhlenbergia torreyi), wolftail (Lycurus phleoides), and galleta (Hilaria jamesii) (Dwyer and Pieper 1967). Other intolerant plants that decrease after fire include sedges (Carex spp.), Idaho fescue (Festuca idahoensis), alpine bluegrass (Poa alpina), common avens (Dryas actopetala), big sagebrush (Artemisia tridentata), and shrubby cinquefoil (Potentilla fruiticosa) (Nimir and Payne 1978).

Fire-intolerant increasers are originally consumed by fire, yet often dominate early post-fire successional stages. Theses

plants increase because of large, highly mobile seed banks and successful stress-avoidance mechanisms. Seed reserves may be stored in the soil, or in the tree canopy in serotinous cones. Manzanita (Arctostaphylos spp.) and ceanothus (Ceanothus spp.) are fire-intolerant shrubs that often increase in post-fire communities. Heat-released seed dormancy is reportedly the reason for increases in these species (Keeley 1977, Fulton and Carpenter 1979, Pase and Lindenmuth 1971). Stone and Juhren (1951) presented evidence that fire enhanced germination and establishment of sugar sumac (Rhus ovata) by rupturing the impermeable seed coat.

PLANT COMMUNITY RESPONSES

There are four community response categories: fire-intolerant, fire-adapted, fire-dependent, and fire-neutral. Each of these community types is affected by unique fire intensity and frequency regimes that are composed of different associations of plant fire-response types. Plant species composition and stand morphology determine community fire response. Fire-response types are dynamic to the extent that a fire-intolerant community may shift to a fire-adapted community with increased fire frequencies.

Fire-intolerant communities are closed-canopy systems on fertile and mesic sites. Both fire-intolerant decreasers and fire-tolerant plants occur within this community type. Spruce-fir forest is an example of a fire-intolerant community. An interval of 60-100 years between fires is typical for this forest (Cattelino et al. 1979). The dominant tree species, Engelmann spruce and subalpine fir (Abies lasiocarpa), may be identified as fire-intolerant decreasers. The prefire abundance of fire-tolerant species, such as aspen, predicts that extent of community change. Where the fire-free interval has been longer than 80-100 years, aspens within the spruce-fir zone are expected to be decadent or absent (Mueller 1976).

When fire frequencies are less than 80 years, aspens--which are strong sprouters--are rejuvenated by fire. In this case, the fire-intolerant spruce-fir forest shifts to a fire-adapted aspen woodland that is an important wildlife habitat (Rowe and Scotter

1973, Singer 1979, Shelford and Olson 1935, Svoboda and Gullion 1972, Kilgore 1971). If aspens are not present, fire-intolerant increasers invade after fire and this community may become fire-dependent, dominated by lodgepole pine (Pinus contorta) or dense shrubs. Lodgepole pine forest is a poor wildlife habitat because in that very few food species are present (Roppe and Hein 1978). A fire frequency that promotes a spruce-fir-aspen complex appears to be desirable for wildlife.

Fire-adapted communities burn every 15-30 years because the location, precipitation, and fuel characteristics conducive to repeated fire. This community type is composed of fire-tolerant and fire-resistant plant species. If fires are suppressed, fire-adapted communities become fire-intolerant communities because of the dense thickets of small trees and shrubs.

Ponderosa pine-grass and aspen-forb associations are fire-adapted plant communities. The annual shedding of long, resinous needles in ponderosa pine forests creates a highly combustible fuel load. Under natural conditions, ground fires every 8-15 years consume needles and other fine fuels but do not damage the mature pines (Weaver 1974). In the Southwest, the fire interval is approximately 3-5 years (Dieterich 1980). The structure of these fire-adapted plant communities is favorable to some wildlife species because open, parklike forests encourage grass and forb diversity and abundance. Elk (Cervus elaphus) and mule deer (Odocoileus hemionus) prefer fire-adapted communities (Ffolliott et al. 1977). Tassel-eared squirrels (Sciurus

aberti), which depend on ponderosa pine, benefit when large, healthy trees produce big seed crops and better cover conditions (Farentinos 1972, Keith 1965).

Chaparral, another fire adapted vegetation type, includes many fire-tolerant species. Sprouting shrubs such as shrub live oak (Quercus turbinella), mountain mahogany (Cercocarpus montanus), skunk bush (Rhus trilobata), banana yucca (Yucca bacata), silktassel (Garrya wrightii), and yerba santa (Eriodictyon angustifolium) are present in both pre- and post-fire communities (Ganes and Jones 1966, Biswell 1974).

Fire-intolerant increasers, also present in chaparral communities, include manzanita (Arctostaphylos pungens, A. pringlei) and deer brier (Ceanothus greggii, C. interrimus, and C. fendleri). These species increase after fire because of heat requirements for seed scarification (Keeley 1977, Pase and Lindenmuth 1971). Burning in chaparral has an important but short-term effect on wildlife habitat because fire-induced openings allow grasses and forbs to increase. Furthermore, sprouts of chaparral species are more nutritious and palatable than mature stems for the first two growing seasons following fire (Hayes 1970, Bendell 1974).

<u>Fire-dependent communities</u> occur where fire frequency is very high. A fire every 1-10 years is typical for a fire-dependent community, but the frequency depends on the composition of the plant community. This community type is generally dominated by fire-intolerant increasers that invade burns by

rapid re-establishment from seed. For example, stands of grasses and forbs in chaparral and forest types disappear when not regenerated by fire. In some Rocky Mountain areas, lodgepole pine stands have established a tight fire-dependent cycle (Vogl 1970). Stands of cheatgrass in sagebrush country depend on control of fire-intolerant sagebrush for existence (Young et al. 1971, Evans and Young 1978, Wright and Britton 1976), and annual grasses and forbs dominate fire-dependent California annual grasslands.

Fire-neutral communities are diverse and may show no change after fire because the plant composition is extremely variable and thus highly resistant to change. A second and more common type of fire neutrality occurs in communities that do not support fuel loads sufficient to carry a fire. For example, desert systems are characterized by scant and unevenly distributed biomass. Fires are typically small and of low intensity. Kittams (1973) cites fuel distribution and levels as reasons for low fire frequency in the Chihuahuan Desert region. Stress-tolerant plant species survive such fires and are often relatively unaffected. Plants such as the century plant (Agave spp.), sotol (Dasylirion wheeleri), juniper, catclaw (Acacia greggii), indigo bush (Dalea spp.), and yucca often survive fire because of stress tolerant abilities.

The community fire-response classifications described are general models intended to simplify complex natural community responses. The ecological role of fire is different for each

vegetation type. The fire history of a plant community influences post-fire succession. Fire may create changes in community structure and wildlife habitat, or may be a necessary perturbation to maintain a particular plant community composition. White (1979) suggests that fire should be considered as a natural disturbance continuum active in communities to varying degrees.

In those communities where fire has historically played an important role, management can be directed at maintaining this function. Allowing for a level of fire disturbance in management planning insures that fire-adapted plant and animal communities will persist. The presence of disturbance-adapted species provides recovery insurance for infrequent natural or man-caused catastrophes.

MANAGEMENT STRATEGIES AND GUIDELINES

There are several general principles that apply and must be considered when using fire as a technique to modify vegetation:

1. Plants have different inherent tolerances to heat because it affects their ability to sprout, regrow, or germinate from seed. Fire can influence plant composition, density, and structure and therefore succession.

2. Any change in vegetation type and structure in time or space can result in a corresponding change in wildlife species

3. Fire may reduce the organic content of soil and release soluble nutrients that can improve plant growth. In addition a seedbed may be created where new species can germinate; and

4. Fire can create a mosaic of habitats from a gradation in environmental conditions that can support a richer composition of plant and animal species.

Forest wildlife biologists must consider the complexities of measuring, predicting, and interpreting the effects, positive or negative, of fire on wildlife species. Some points to keep in mind are:

1. Recognize when an action should be taken to modify the food and/or cover for a specific species, or for a combination of species.

2. Determine how to create the desired effect through a specific treatment.

3. Outline how to measure the results of your actions and repeat the treatment to get similar results.

4. On the basis of the actions you have taken, be able to predict both the short and long term effects of the treatment on different wildlife species.

In using fire to benefit wildlife the biologist and fire technician have to overcome many barriers, including not having adequate information on how fire affects the many different animal species in a vegetation type. Some suggestions to overcome these barriers are indicated from personal experience of those who have worked with the issues (Dieterich, personnal communication 1990) such as:

1. Revisit fires where you have been involved and observe the different tree age classes, vegetation types, and try to determine season of burn and burning conditions; then evaluate the effects in terms of acceptability of meeting stated objectives.

2. Use literature and references that contain information applicable to your specific area and need.

3. If the district fire organization is to conduct the burning operation, explain what you want to accomplish in vegetation manipulation and discuss with them the type of fire needed to meet these objectives.

4. When using your fire organization, ask them to provide a quantitative description of the fire attributes.

5. Keep good field notes and do not rely on memory to recall observations.

6. Locate observation points and take many photographs and write detailed descriptions that later become permanent records.

Management Matrix

From the information available, a management matrix can be constructed that approximates the effects of fire on broad groups of wildlife species. These groups are created by using home ranges and animal mobility. The matrix presented below is not exact because information on individual species within the mobility groups is not exact. The matrix is based on immediate (<3 years) and long term (>3 years) effects and is a composite rating that considers food and cover (See Appendix F for justifications for ratings). Fire frequency also has an effect but sufficient information is not available to incorporate it into the matrix.

Information in the matrix can be used along with information on each species in the fire response classifications (pages 14-20) and from individual accounts (Appendices A, B, and C) to arrive at an approximation of how a prescribed fire with given attributes will affect wildlife species for a specific location.

Approximate Effects of Fire on Wildlife Species.

Animal Mobility	Low <3	Low >3 years	Moderate <3	Moderate >3 years	High <3	High >3 years
Low	o	+	-	-	-	-
Moderate	o	+	o	+	-	-
High	o	+	o	+	-	+

(Fire Intensity)

Positive (+) No Change (o) Negative (-)

Animal Mobility

Low (yards)

Small rodents
Small birds
Salamanders
Frogs
Snakes

Moderate (acres)

Fox
Skunks
Raccoons
Some Squirrels

High (miles)

Deer
Elk
Turkey
Bear

Fire Intensity

Low

Minor amounts of exposed soil.

Moderate

A loss of a few dead trees and snags.

High

Large amounts of soil exposed.
Almost total destruction of snags.
>50% of trees killed.

Appendix E and F provide additional information.

Where Do We Go From Here

Information is lacking on how to describe the benefits or loss of habitat for different animal species as it relates to fire intensity. The problem is one of describing what is or has been a fire, that could range from warm to hot, and how the intensity relates to vegetation that remains as food or cover for various species. The literature does not provide information of the type needed and of sufficient quality to arrive at a good fire intensity rating system for wildlife habitat. The management matrix that uses three fire intensity ratings is only a first approximation that will have to be modified as new information accumulates from experience and research.

The information on fire-intolerant, fire-impervious, fire adapted, and fire dependent animal species has already been added as a column in the ANIMALS relation in R3HARE (Region 3 Habitat Relationships). These classifications also are approximations and the four classes may reflect an accuracy that is not present. Work is needed to revise the fire response classifications to three or to verify that four classes are real.

Because prescribed burns will be used more in the future as one tool to restore ecosystem health, it is important to start now to develop protocols for the use of fire for manipulating wildlife habitats. One way to do this is through a committee of appointed personnel that has a specific assignment and meets on a regular basis to develop guidelines and procedures.

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LITERATURE CITED

1. Ahlgren, Clifford E. 1966. Small mammals and reforestation following prescribed burning. Journal of Forestry 64(9):614-618.

2. Anderson, Henry W. 1974. Fire effects on water supply, floods and sedimentation. Tall Timbers Fire Ecology Conference 15:249-260.

3. Arnold, Joe F. 1963. Uses of fire in the management of Arizona watersheds. Tall Timbers Fire Ecology Conference 2:99-111.

4. Baker, W. Wilson. 1974. Longevity of lightning struck trees and notes on wildlife use. Tall Timbers Fire Ecology Conference 13:497-504.

5. Balda, Russell P. 1975. Vegetation structure and breeding bird diversity. p. 59-80. In Proceedings of the Symposium on Management of Forest and Range Habitats for Non-Game Birds. [Tucson, Ariz., May 6-9, 1975]. USDA Forest Service General Technical Report WO-1. Washington, D.C.

6. Baldwin, J.J. 1968. Chaparral conversion on the Tonto National Forest. Tall Timbers Fire Ecology Conference 8:203-208.

7. Basile, Joseph V. 1979. Elk-aspen relationships on a prescribed burn. USDA Forest Service Research Note INT-271, 7 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

8. Beck, A.M., and R.J. Vogl. 1972. The effects of spring burning on rodent populations in a brush prairie savannah. Journal of Mammalogy 53(2):336-345.

9. Bell, M.M., and G.H. Studinski. 1972. Habitat manipulation and its relationship to avian and small rodent populations on the Descanso District of the Cleveland National Forest. USDA Forest Service. Unpublished Report on file at Cleveland National Forest. San Diego, Calif.

10. Bendell, J.F. 1974. Effects of fire on birds and mammals. In Fire and Ecosystems. T.T. Kozlowski and C.E. Ahlgren, editors. Academic Press. New York, N.Y. 545 p.

11. Bendell, J.F., and P.W. Elliot. 1966. Habitat selection in blue grouse. Condor 68:431-446.

12. Best, Louis B. 1972. First-year effects of sagebrush control on two sparrows. Journal of Wildlife Management 36(2):534-543.

13. Biswell, Harold H. 1969. Prescribed burning for wildlife in California brushlands. Transactions of the Thirty-Fourth North American Wildlife Conference. p. 438-446.

14. Biswell, Harold H. 1973. Fire ecology in ponderosa pine-grassland. Tall Timbers Fire Ecology Conference 12:69-96.

15. Biswell, Harold H. 1974. Effects of fire on chaparral. In Fire and Ecosystems. T. T. Kozlowski and C.E. Ahlgren, editors. Academic Press, New York, N.Y. p. 321-364.

16. Biswell, Harold H., and P.C. Lemon. 1944. Effect of fire upon seed-stalk production of range grasses. Journal of Forestry 41:844.

17. Blackford, J.L. 1955. Woodpecker concentration in burned forest. Condor 57:28-30.

18. Brock, Jane H. Carl E. Bock, and J.R. McKnight. 1976. A study of the effects of grassland fires at the Research Ranch in southeastern Arizona. Journal of the Arizona Academy of Science 11:49-57.

19. Bock, Carl E., and Jane E. Lynch. 1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. Condor 72:182-189.

20. Boeker, Erwin L., and Virgil E. Scott. 1969. Roost tree characteristics for Merriam's turkey. Journal of Wildlife Management 3(1):121-124.

21. Boeker, Erwin L., Virgil E. Scott, H.G. Reynolds, and B.A. Donaldson. 1972. Seasonal food habitats of mule deer in southwestern New Mexico. Journal of Wildlife Management 36(1):56-63.

22. Boussu, Marvin F. 1954. Relationship between trout populations and cover on a small stream. Journal of Wildlife Management 18(2):229-239.

23. Bradley, W. Glen, and Roger A. Mauer. 1973. Rodents of a creosote brush community in southern Nevada. Southwestern Naturalist 17(4):333-344.

24. Brown, David E. 1978. Grazing, grassland cover and gamebirds. Transactions of the Thirty-Fourth North American Wildlife Conference. p. 477-485.

25. Brown, David E., and Ronald H. Smith. 1980. Winter-spring precipitation and population levels of blue grouse in Arizona. Wildlife Society Bulletin 8(2):136-140.

26. Brown, G.W. 1970. Predicting the effects of clear-cutting on stream temperatures. Journal of Soil and Water Conservation 21:11-13.

27. Bunting, S.C., H.A. Wright, and L.F. Neuenschwander. 1980. Long-term effects of fire on cactus in the southern mixed prairie of Texas. Journal of Range Management 33(2):85-88.

28. Burns, E.H. 1977. Winter behavior of pronghorns in relation to habitat. Journal of Range Management 41(3):560-571.

29. Buttery, Robert F., and P.W. Shields. 1975. Range management practices and bird habitat values. In Proceedings of the Symposium on management of forests and range habitats for non-game birds. [Tucson, Ariz., May 6-9, 1975]. USDA Forest Service General Technical Report WO-1. p. 183-189.

30. Cable, Dwight R. 1967. Fire effects on semi-desert grasses and shrubs. Journal of Range Management 20(3):170-176.

31. Cable, Dwight R. 1973. Fire effects in southwestern semi-desert grass-shrub communities. Tall Timbers Fire Ecology Conference 12:109-127.

32. Carmichael, R.S., O.D. Knipe, C.P. Pase, and W.W. Brady. 1978. Arizona chaparral plant associations and ecology. USDA Forest Service Research Paper RM-202, 16 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

33. Carpenter, L.H., O.C. Wallmo, and R.B. Gill. 1979. Forage diversity and dietary selection by wintering mule deer. Journal of Range Management 32(3):226-229.

34. Cattelino, P.J., I.R. Noble, R.O. Slatyer, and S.R. Kessell. 1979. Predicting the multiple pathways of plant succession. Environmental Management 3(1):41-50.

35. Clark, H.W. 1935. Fire and bird populations. Condor 37:16-18.

36. Conner, R. N., D. C. Rudolph, D. L. Kulhavy, and A. E. Snow. 1991. Causes of mortality of red-cockaded woodpecker cavity trees. J. Wildl. Manage. 55:531-537.

36. Cook, Sherberne F. 1959. The effects of fire on a population of small rodents. Ecology 40(1):102-108.

37. Cooper, Charles F. 1961. Controlled burning and watershed condition in the White Mountains of Arizona. Journal of Forestry 59(6):438-442.

38. Costa, Ralph, Peter F. Ffolliott, and David R. Patton. 1976. Cottontail response to forest management in southwestern ponderosa pine. USDA Forest Service Research Note RM-330, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

39. Curtis, John T., and M.L. Partch. 1950. Some factors affecting flower production in Andropogon gerardi. Ecology 31(3):488-489.

40. Dasmann, Raymond F. 1966. Wildlife biology. John Wiley and Sons, New York, N.Y. 231 p.

41. Dasmann, William, R. Hubbard, W.G. McGregor, and A.E. Smith. 1967. Evaluation of the wildlife results from fuel breaks, browse-ways and type conversions. Tall Timbers Fire Ecology Conference 7:179-193.

42. Daubenmire, R. 1968. Ecology of fire in grasslands. In Advances in Ecological Research. Vol. 5. Academic Press, New York, N.Y. p. 209-273.

43. Davis, C.A., R.C. Barkley, and W.C. Haussamen. 1975. Scaled quail food in southeastern New Mexico. Journal of Wildlife Management 39(3):496-502.

44. Davis, R.P. 1977. Cervid response of forest fire and clearcutting in southeastern Wyoming. Journal of Wildlife Management 41(4):785-788.

45. De Byle, Norbert V. 1976. Soil fertility as affected by broadcast burning following clearcutting in northern Rocky Mountain larch/fir forests. Tall Timbers Fire Ecology Conference 14:447-464.

46. Dewitt, J. B., and J. V. Derby, Jr. 1955. Changes in nutritive value of browse plants following forest fire. J. Wildl. Manage. 19:65-70.

47. Dills, Gary G. 1970. Effects of prescribed burning on deer browse. Journal of Wildlife Management 34(3):540-545.

48. Dwyer, Don D., and Rex D. Pieper. 1967. Fire effects on blue grama-pinyon-juniper rangeland in New Mexico. Journal of Range Management 29(6):359-362.

49. Edwards, R.Y. 1954. Fire and the decline of a mountain caribou herd. Journal of Wildlife Management 18(4):521-526.

50. Evans, R.A., and J.A. Young. 1978. Effectiveness of rehabilitation practices following wildfire in a degraded big sagebrush-downy brome community. Journal of Range Management 31(3):185-188.

51. Farentinos, Robert C. 1972. Observations on the ecology of the tassel-eared squirrel. Journal of Wildlife Management 36(4):1234-1239.

52. Ffolliott, Peter F., Ron E. Thill, Warren P. Clary, and Fred R. Larson. 1977. Animal use of ponderosa pine forest openings. Journal of Wildlife Management 41(4):782-784.

53. Fitzhugh, E. Lee, John E. Cornley, and Jean T. Beaulieu. 1978. The battle burn: disaster or blessing for wildlife. In Putting biology back into wildlife management. Transactions of the Arizona-New Mexico Chapters, The Wildlife Society.

54. Franzreb, Kathleen E. 1977. Bird population changes after timber harvesting of a mixed conifer forest in Arizona. USDA Forest Service Research Paper RM-184, 26 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

55. Fulton, R.E., and F.L. Carpenter. 1979. Pollination, reproduction and fire in California Arctostaphylos. Oecologia 38:147-157.

56. Geier, A.R., and L.B. Best. 1980. Habitat selection by small mammals of riparian communities: Evaluating effects of habitat alterations. Journal of Wildlife Management 44(1):16-24.

57. Givens, L.S. 1962. Use of fire on southwestern wildlife refuges. Tall Timbers Fire Ecology Conference 1:121-126.

58. Grime, J.P. 1979. Plant strategies and vegetation processes. John Wiley and Sons, New York, N.Y. 222 p.

59. Gruell, G.E. 1980. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Vol. II. USDA Forest Service General Technical Report INT-252, 35 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

60. Habeck, J.R., and R.W. Mutch. 1973. Fire-dependent forests in the northern Rocky Mountains. Quaternary Research 3:408-424.

61. Hadley, Elmer B., and Barbara J. Kieckhefer. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44(2):389-395.

62. Hagar, Donald C. 1960. The inter-relationships of logging, birds and timber regeneration in the Douglas-fir region of northwestern California. Ecology 41(1):116-125.

63. Hallisey, D.M., and G.W. Wood. 1976. Prescribed fire in scrub oak habitat in central Pennsylvania. Journal of Wildlife Management 49(3):507-516.

64. Handley, Charles O. Jr. 1969. Fire and mammals. Tall Timbers Fire Ecology Conference 9:151-159.

65. Hanes, Ted L., and Harold W. Jones. 1966. Post-fire chaparral succession in southern California. Ecology 48(2):259-264.

66. Hanson, E.E. 1978. The impact of a prescribed burn in a temperate subalpine forest upon the breeding bird and small mammal populations. M.S. thesis, Central Washington University, Ellensburg.

67. Hayes, G.L. 1970. Impacts of fire use on forest ecosystems. p. 99-118. In The Role of Fire in the Intermountain West. Symposium Proceedings, School of Forestry, Intermountain Fire Research Council. Missoula, Mont.

68. Heinselman, Miron L. 1970. The natural role of fire in northern conifer forests. p.30-41. In The Role of Fire in the Intermountain West. Symposium Proceedings, School of Forestry Intermountain Fire Research Council. Missoula, Mont.

69. Heinselman, Miron L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3:329-382.

70. Hendricks, Jared H. 1968. Control burning for deer management in chaparral in California. Tall Timbers Fire Ecology Conference 8:219-233.

71. Howard, W.E., R.L. Fenner, and H.E. Childs, Jr. 1959. Wildlife survival in brush burns. Journal of Range Management 12:230-234.

72. Johnson, Donald E., Hashim A. M. Mukhtar, Raymond Mapston, and R.R. Humphrey. 1962. The mortality of oak-juniper woodland species following a wildfire. Journal of Range Management 15(4):201-205.

73. Keay, J.A., and J.M. Peck. 1980. Relationship between fires and winter habitat of deer in Idaho. Journal of Wildlife Management 44(2):372-380.

74. Keeley, J.E. 1977. Seed production, seed populations in soil, and seedling production after fire for two congeneric pairs of sprouting and non-sprouting chaparral shrubs. Ecology 58(4):820-829.

75. Keith, James O. 1965. The Abert squirrel and its dependence on ponderosa pine. Ecology 46:150-162.

76. Kilgore, B.M. 1971. Response of breeding bird populations to habitat changes in a giant sequoia forest. American Midland Naturalist 85(1):135-152.

77. Kilgore, B.M. 1973. The ecological role of fire in Sierran conifer forests: Its application to National Park management. Quaternary Research 3:496-513.

78. Kirsch, Leo M., and Arnold D. Kruse. 1973. Prairie fires and wildlife. Tall Timbers Fire Ecology Conference 12:289-303.

79. Kittams, Walter H. 1973. Effects of fire on vegetation of the Chihuahuan Desert region. Tall Timbers Fire Ecology Conference 12:427-444.

80. Koehler, A.V. 1975. Preserving the pine marten: Management guidelines for western forests. Western Wildlands 2(3):31-36.

81. Komarek, E.V., Sr. 1969. Fire and animal behavior. Tall Timbers Fire Ecology Conference 9:161-207.

82. Komarek, E.V., Sr. 1976. Fire ecology review. Tall Timbers Fire Ecology Conference 14:201-216.

83. Komarek, Roy. 1963. Fire and the changing wildlife habitat. Tall Timbers Fire Ecology Conference 2:35-43.

84. Koplin, J.R. 1969. The numerical response of woodpeckers to insect prey in a subalpine forest in Colorado. Condor 71:436-438.

85. Koya, C.M. 1977. Reproductive biology of rainbow and brown trout in a geothermally heated stream: The Firehole River of Yellowstone National Park. American Fisheries Society Transactions 106(4):354-361.

86. Kruse, William H. 1972. Effects of wildfire on elk and deer use of a ponderosa pine forest. USDA Forest Service Research Note RM-226, 4 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

87. Lauckhart, J.B. 1955. The effect of logging old growth timber on bear. Proceedings of the Society of American Foresters 1954:122-130.

88. Lawrence, George E. 1966. Ecology of vertebrate animals in relation to chaparral fire in the Sierra Nevada foothills. Ecology 47(2):278-290.

89. Lay, Daniel W. 1967. Browse palatability and the effects of prescribed burning in southern pine forests. Journal of Forestry 65(11):826-828.

90. Leege, R.A., and W.O. Hickey. 1971. Sprouting of northern Idaho shrubs after prescribed burning. Journal of Wildlife Management 35(3):508-515.

91. Leege, T.A. 1968. Prescribed burning for elk in northern Idaho. Tall Timbers Fire Ecology Conference 8:235-253.

92. Leege, Thomas A. 1969. Burning seral brush ranges for big game in northern Idaho. Transactions of the Thirty-Fourth North American Wildlife Conference. p. 429-438.

93. Leopold, A. Starker. 1950. Deer in relation to plan succession. Journal of Forestry 48(10):675-678.

94. Leopold, Aldo. 1923. Wild followers of the forest: The effect of forest fires on game and fish. American Forestry 29:515-519.

95. Lichtkoppler, Frank, and Claude E. Boyd. 1977. Phosphorus fertilization of sunfish ponds. American Fisheries Society Transactions 106(6):634-636.

96. Lillywhite, H.B. 1977. Animal response to fire and fuel management in chaparral.p. 368-373. In Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. [Palo Alto, Calif., August 1-5, 1977]. USDA Forest Service General Technical Report WO-3, Washington, D.C.

97. Line, L. 1964. The bird worth a forest fire. Audubon 66:370-375.

98. Longstreth, D.J., and Duncan T. Patten. 1975. Conversion of chaparral to grass in central Arizona: Effects on selected ions in watershed runoff. American Midland Naturalist 93(1):25-34.

99. Lowe, Philip O., Peter F. Ffolliott, John H. Dieterich, and David R. Patton. 1978. Determining potential wildlife benefits from wildfire in Arizona ponderosa pine forests. USDA Forest Service General Technical Report RM-52, 12 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

100. Lyon, L. Jack, H.S. Crawford, E. Czuhai, R. L. Fredriksen, R.F. Harlen, L.J. Metz, and Henry A. Pearson. 1978. Effects of fire on fauna: A state-of-knowledge review. USDA Forest Service General Technical Report WO-6, 22 p. Washington, D.C.

101. Lyon, L. Jack, and Peter F. Stickney. 1976. Early vegetal succession following large northern Rocky Mountain wildfires. Tall Timbers Fire Ecology Conference 14:355-375.

102. Mannan, R.W. 1980. Assemblages of bird species in western coniferous old-growth forests. In Workshop proceedings on management of western forests and grasslands for non-game birds. USDA Forest Service General Technical Report INT-86. p. 357-368. Intermountain Forest and Range Experiment Station, Ogden, Utah.

103. Marshall, Joe T. 1963. Fire and birds in the mountains of southern Arizona. Tall Timbers Fire Ecology Conference 2:135-141.

104. Martinka, C.J. 1967. Fire and elk in Glacier National Park. Tall Timbers Fire Ecology Conference 14:377-389.

105. Mazurek, E.J. 1981. Effect of fire on small mammals and vegetation on the Upper Sonoran Desert. M.S. thesis. Arizona State University, Tempe, Ariz.

106. McCulloch, Clay Y. 1969a. Role of fire in game management in Arizona. In Proceedings of the symposium on fire and the control and use of fire in wildlife management [Tucson, Ariz.]. p. 69-72.

107. McCulloch, Clay Y. 1969b. Some effects of wildfire on deer habitat in pinyon-juniper woodland. Journal of Wildlife Management 33(4):778-784.

108. Michael, Edwin I., and Patrick I. Thornburgh. 1971. Immediate effects of hardwood removal and prescribed burning on bird populations. Southwestern Naturalist 15(3):357-370.

109. Miller, Howard A. 1963. Use of fire in wildlife management. Tall Timbers Fire Ecology Conference 15:85-102.

110. Mueggler, Walter F. 1976. Ecological role of fire in western woodland and range ecosystems. In Use of prescribed burning in western woodland and range ecosystems: A Symposium. Utah Agricultural Experimental Station, Utah State University, Logan, p. 1-9.

111. Nelson, J.R. 1974. Forest fire and big game in the Pacific Northwest. Tall Timbers Fire Ecology Conference 15:85-102.

112. Nimir, M.B., and G.F. Payne. 1978. Effects of spring burning on a mountain range. Journal of Range Management 31(4):259-263.

113. Pase, Charles P., and A.W. Lindenmuth, Jr. 1971. Effects of prescribed fire on vegetation and sediment in oak-mountain mahogany chaparral. Journal of Forestry 69(11):800-804.

114. Patton, David R. 1978. RUN WILD: A storage and retrieval system for wildlife habitat information. USDA Forest Service General Technical Report RM-51, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

115. Patton, David R., and John R. Jones. 1977. Managing aspen for wildlife in the southwest. USDA Forest Service General Technical Report RM-37, 7 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

116. Pederson, J.C., and K.T. Harper. 1978. Factors influencing productivity of two mule deer herds in Utah. Journal of Range Management 31(2):105-110.

117. Perkins, Carroll J. 1968. Controlled burning in the management of muskrats and waterfowl in Louisiana coastal marshes. Tall Timbers Fire Ecology Conference 8:269-280.

118. Pulliam, H.R., and G.S. Mills. 1977. The use of space by wintering sparrows. Ecology 58(6):1393-1399.

119. Ralston, Charles W., and Glyndon E. Hatchell. 1971. Effects of prescribed burning on physical properties of soil. In Prescribed Burning Symposium. [Charleston, S.C., April 14-16, 1971]. USDA Forest Service Southeastern Forest Experiment Station, Asheville, N.C. 160 p.

120. Redfield, J.A. 1970. Effects of fire on numbers of blue grouse. Tall Timbers Fire Ecology Conference 10:63-83.

121. Reichman, O.J., and K.M. VandeGraaff. 1975. Association between ingestion of green vegetation and desert rodent reproduction. Journal of Mammalogy 56(2):503-509.

122. Renwald, J.D., et al. 1978. Effects of prescribed fire on bob-white quail habitat in the rolling plains of Texas. Journal of Range Management 31(1):65-69.

123. Reynolds, Hudson G. 1969. Improvement of deer habitat on southwestern forest lands. Journal of Forestry 69:803-805.

124. Roppe, Jerry A., and Dale Hein. 1978. Effects of fire on wildlife in a lodgepole pine forest. Southwestern Naturalist 23(2):279-288.

125. Rowe, J.S., and G.W. Scotter. 1973. Fire in the Boreal Forest. Quaternary Research 3:444-464.

126. Schlichtemeier, G. 1967. Marsh burning for waterfowl. Tall Timbers Fire Ecology Conference 6:41-46.

127. Schroeder, M.H., and D.L. Sturges. 1975. The effect on the Brewer's sparrow of spraying big sagebrush. Journal of Range Management 28(4):294-297.

128. Schubert, Gilbert H. 1974. Silviculture of southwestern ponderosa pine: The state of our knowledge. USDA Forest Service Research Paper RM-123, 71 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

129. Scott, Virgil E., and Erwin L. Boeker. 1977. Responses of Merriam's turkey to pinyon-juniper control. Journal of Range Management 30(3):220-223.

130. Shelford, Victor E., and S. Olsen. 1935. Sere, climax and influent animals with special reference to the transcontinental coniferous forest of North America. Ecology 16(3):375-402.

131. Short, Henry L. 1977. Food habits of mule deer in a semi-desert grass-shrub habitat. Journal of Range Management 30(3):206-209.

132. Short, Henry L. 1979. Deer in Arizona and New Mexico: Their ecology and a theory explaining recent population decreases. USDA Forest Service General Technical Report RM-70, 25 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

133. Short, Henry L., Wain Evans, and Erwin L. Boeker. 1977. The use of natural and modified pinyon pine-juniper woodlands by deer and elk. Journal of Wildllife Management 41(3):543-559.

134. Short, Henry L., and Clay Y. McCulloch. 1977. Managing pinyon-juniper ranges for wildlife. USDA Forest Service General Technical Report RM-47, 10 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

135. Singer, F.J. 1979. Habitat partitioning and wildfire relationships of cervids in Glacier National Park, Montana. Journal of Wildlife Management 43(2):437-444.

136. Smith, E.F., and C.E. Owensby. 1973. Effects of fire on true prairie grasslands. Tall Timbers Fire Ecology Conference 12:9-22.

137. Soutiere, Edward C., and Eric G. Bolen. 1973. Role of fire in mourning dove nesting ecology. Tall Timbers Fire Ecology Conference 12:277-288.

138. Stark, N. 1976. Fuel Reduction - nutrient status and cycling relationship associated with understory burning in larch/Douglas-fir stands. Tall Timbers Fire Ecology Conference 14:573-596.

139. Stoddard, Herbert L. 1963. Bird habitat and fire. Tall Timbers Fire Ecology Conference 2:163-175.

140. Stokes, Marvin A., and John H. Dieterich. (Technical Coordinators) 1980. Proceedings of the fire history workshop. [Tucson, Ariz., October 20-24, 1980]. USDA Forest Service General Technical Report RM-81, 142 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

141. Stone, E.C., and G. Juhren. 1951. The effect of fire on the germination of the seed Rhus ovata Wats. Journal of Botany 38(5):368-372.

142. Svoboda, F.J., and G.W. Gullion. 1972. Preferential use of aspen by ruffed grouse in northern Minnesota. Journal of Wildlife Management 36(4):1166-1180.

143. Swanston, D.N. 1980. Influence of forest and rangeland management on anadromous fish habitat in western North America: Impacts of natural events. USDA Forest Service General Technical Report PNW-104, 27 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

144. Szaro, Robert C., and Russell p. Balda. 1979. Bird community dynamics in a ponderosa pine forest. Cooper Ornithological Society, Flagstaff, Ariz. 66 p.

145. Taylor, Dale L. 1969. Biotic succession of lodgepole pine forests of fire origin in Yellowstone National Park. Ph.D. dissertation, University of Wyoming, Laramie.320 p.

146. Taylor, Dale L. 1976. Forest fires and the tree-hole nesting cycle in Grand Teton and Yellowstone National Parks. In Conference on Scientific Research in the National Parks. [New Orleans, La.], Vol. I., pp. 509-511.

147. Taylor, Dale L., and W.L. Barmore. 1980. Post-fire succession of avifauna in coniferous forests of Yellowstone and Grand Teton National Parks, Wyoming. p. 130-145, In Management of western forests and grasslands for non-game birds workshop proceedings. [Salt Lake City, Utah, February 11-14, 1980]. USDA Forest Service General Technical Report INT-86. Intermountain Forest and Range Experiment Station, Ogden, Utah.

148. Tevis, Lloyd Jr. 1956. Effect of a slash burn on forest mice. Journal of Wildlife Management 29(4):405-409.

149. Thomas, Jack Ward, editor. 1979. Wildlife habitat in managed forests of the Blue Mountains of Oregon and Washington. USDA Forest Service Agricultural Handbook 53, 512 p. Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

150. Viro, P. J. 1974. 1974. Effects of fire on soil. In Fire and Ecosystems. T. T. Kozlowski and C.E. Ahlgren, editors. Academic Press, New York, N.Y. 542 p.

151. Vogl, Richard J. 1967. Fire adaptations of some southern California plants. Tall Timbers Fire Ecology Conference 7:78-109.

152. Vogl, Richard J. 1970. Fire and plant succession. p. 65-75. In The role of fire in the Intermountain West. Symposium Proceedings. School of Forestry, Intermountain Fire Research Council. Missoula, Mont.

153. Wallmo, Olof C., L.H. Carpenter, W.L. Regelin, R.B. Gill, and D.L. Baker. 1977. Evaluation of deer habitat on a nutritional basis. Journal of Range Management 30(2):122-127.

154. Wallmo, Olof C., Wayne L. Regelin, and Donald W. Reichert. 1972. Forage use by mule deer relative to logging in Colorado. Journal of Wildlife Management 36(4):1025-1033.

155. Walter, Hartmut. 1977. Effects of fire on wildlife communities. p. 183-192. In Proceedings of the Symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. [Palo Alto, Calif., August 1-5, 1977]. USDA Forest Service General Technical Report WO-3. Washington, D.C.

156. Ward, Peter. 1968. Fire in relation to waterfowl habitat of the delta marshes. Tall Timbers Fire Ecology Conference 8:254-267.

157. Weaver, Harold. 1967. Fire and its relationship to ponderosa pine. Tall Timbers Fire Ecology Conference 7:127-149.

158. Weaver, Harold. 1974. Effects of fire on temperate forest: Western United States. p. 279-319. In Fire and Ecosystems. T.T. Kozlowski and C.E. Ahlgren, editors. Academic Press, New York, N.Y.

159. Wellner, C.A. 1970. Fire history in the northern Rocky Mountains. p. 42-64. In Fire and Ecosystems. T.T. Kozlowski and C.E. Ahlgren, editors. Academic Press, New York, N.Y.

160. White, P.S. 1979. Pattern, process and natural disturbance in vegetation. Botanical Review 45(3):229-299.

161. Whysong, Gary L., and M.H. Heisler. 1978. Nitrogen levels of soil and vegetation in the Upper Sonoran Desert as affected by fire. Proceedings First International Rangeland Conference [Denver, Colo., August 14-18]. Society for Range Management.

162. Wicker, Ed F., and C.D. Leaphart. 1976. Fire and dwarf mistletoe (Arceuthobium spp.) relationships in the northern Rocky Mountains. Tall Timbers Fire Ecology Conference 14:279-298.

163. Williams, O. 1955. Distribution of mice and shrews in a Colorado montane forest. Journal of Mammalogy 36(2):221-231.

164. Wirtz, William O. 1977. Vertebrate post-fire succession. p. 46-57. In Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems. [Palo Alto, Calif., August 1-5, 1977]. USDA Forest Service General Technical Report WO-3. Washington, D.C.

165. Wolfe, Carl W. 1973. Effects of fire on a sand hills grassland environment. Tall Timbers Fire Ecology Conference 12:241-255.

166. Wright, Henry A. 1974a. Range burning. Journal of Range Management 27(1):5-11.

167. Wright, Henry A. 1974b. Effect of fire on southern mixed prairie grasses. Journal of Range Management 27(6):417-419.

168. Wright, Henry A., and C.M. Britton. 1976. Fire effects on vegetation in western rangeland communities. In Use of prescribed burning in western woodland and range ecosystems: A symposium. Utah Agriculture Experiment Station, Utah State University, Logan, p. 35-41.

169. Wright, Henry A., S.C. Bunting, and L.F. Neuenschwander. 1976. Effects of fire on honey mesquite. Journal of Range Management 29(6):467-471.

170. Wright, Henry A., Francis M. Churchill, and W. Clark Stevens. 1976. Effects of prescribed burning on sediment water yields and water quality from dozed juniper land in central Texas. Journal of Range Management 29(4):294-298.

171. Wright, Henry A., and M.L. Heinselman. 1973. The ecological role of fire in natural conifer forests of western and northern North America. Quaternary Research 3:317-328.

172. Young, J.A., R.A. Evans, and J. Major. 1971. Alien plants in the Great Basin. Journal of Range Management 24:194-200.

173. Zwolinski, Malcolm J., and John H. Ehrenreich. 1967. Prescribed burning on Arizona watersheds. Tall Timbers Fire Ecology Conference 7:195-205.

174. Baker, R.H. 1968. Habitats and distribution. Pages 98-126 in King, J.A. (ed.) Biology of Peromyscus (Rodentia). American Society of Mammalogists, OK.

175. Barnes, V.G. Jr, 1974. Response of pocket gopher populations to silvicultural practices in central oregon. In Wildlife and forest management in the pacific northwest. p. 267-276. 1973 Symp. Ore. State Unive, Corvalis.

176. Belk, M.C., H.D. Smith, and J. Lawson. 1988. Use and partitionaing of montane habitat by small mammals. J. Mamm. 69:688-695.

177. Black, H.C., E.H. Hooven. 1974. Response of small mammal communities to habitat changes in western oregon. In Wildlife and forest management in the pacific northwest. P 177-186. Proc. 1973 Symp. Ore. State Univ, Corvalis.

178. Blake, J.G. 1982. Influence of fire and logging on nonbreeding bird communities of ponderosa pine forests. J. Wildl. Manage. 46: 404-415.

179. Buckner, J. L., and J. L. Landers. 1979. Fire and disking effects on herbaceous food plants and seed supplies. J. Wildl. Manage. 43:807-811.

180. Carlson, P. C. , G. W. Tanner, J. M. Wood, and S. R. Humphrey. 1993. Fire in Key deer habitat improves browse, prevents succession, and preserves endemic herbs. J. Wildl. Manage. 57:914-928.

181. Davis, P.R. 1976. Response of vertebrate fauna to forest fire and clearcutting in south central wyoming. USDA For. Serv. and univ. of wyoming coop agreements nos 16-391-ca and 16-464-ca. 94p.

182. Dieterich, John H. 1980. Chimney Spring forest fire history. USDA Forest Service Research Paper RM-220, 8 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

183. Dimock, E.J.II., 1974. Animal populations and damage. In environmental effects of forest residues management in the pacific northwest. USDA For. Serv. Gen Tech. Rep. PNW-24. Pac. Nw. For. and Range Exp. Stn, Portland, Oregon.

184. Drickamer, L.C. 1970. Seed preferences in wild caught Peromyscus maniculatus bairdii and Peromyscus leucopus noveboracesnsis. J. Mamm. 51(1): 191-194.

185. Gashwiler, J.S. 1959. Small mammal study in west-central oregon. J. Mamm. 40: 128-138.

186. Gurevitch, J., and S. L. Collins. 1994. Experimental manipulation of natural plant communities. Trends in Ecology and Evolution. 9:94-98.

187. Halvorson, C.H. 1981. Small mammal populations. In clearcutting and fire in the larch-fir forests of western montana -- a multifaceted research summary. USDA For. Serv Gen. Tech. Rep. Int-99. Internt. For. and Range Exp. Stn., Ogden, Utah.

188. Horton, S. P., and R. W. Mannan. 1988. Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. Wildl. Soc. Bull. 16:37-44.

189. Irvine, L.R. 1991. Disturbance and small mammals: effects of prescribed fire on white-footed mice (Peromyscus). Masters thesis. Northern Arizona University.

190. Jakubas, W. J., R. A. Garrott, P. J. White, and D. R. Mertens. 1994. Fire-induced changes in the nutritional quality of lodgepole pine bark. Journ. Wildl. Manage. 58:35-46.

191. Jameson, E.W., Jr. 1952. Food of deer mice, Peromyscus maniculatus and P. boylii, in the northern Sierra Nevada, California. J. Mamm. 33(1): 50-60.

192. Koehler, G. M. and M. G. Hornocker. 1977. Fire effects on marten habitat in the Selway-Bitterroot Wilderness. J. Wildl. Manage. 41:500-505.

193. Lovaas, A. L. 1976. Introduction of prescribed burning to Wind Cave National Park. Wildl. Soc. Bull. 4:69-73.

194. Masters, R. E., R. L. Lochmiller, and D. M. Engle. 1993. Effects of timber harvest and prescribed fire on white-tailed deer forage production. Wildl. Soc. Bull. 21:401-411.

195. Masters, R. E. 1993. Effects of timber harvest and prescribed fire on white-tailed deer forage production. Wildl. Soc. Bull. 21:401-411.

196. McMurry, S. T., R. L. Lochmiller, J. F. Boggs, D. M. Leslie, and D. M Engle. 1994. Demographic profiles of populations of cotton rats in a continuum of habitat types. J. of Mamm. 75:50-59.

197. Merrill, E. H., H. F. Mayland, and J. M. Peek. 1982. Shrub respnses after fire in an Idaho ponderosa pine community. J. Wildl. Manage. 46:496-502.

198. O'Halloran, K. A., R. M. Blair, R. Alcaniz, and H. F. Morris, Jr. 1987. Prescribed burning effects on production and nutirent composition of fleshy fungi. J. Wildl. Manage. 51:258-262.

199. Parren, S.G. and D.E. Capen. 1985. Local distribution and coexistence of two species of Peromyscus in Vermont. J. Mamm. 66:36-44.

200. Sietman, B. E., W. B. Fothergill, and E. J. Finck. 1994. Effects of haying and old-field succession on small mammals in tallgrass prarie. Amer. Midland Natur. 131:1-8.

201. Spires, S., J.F. Bendell. 1982. Resources and dynamics of the boreal zone. In Proceedings of a conferences held at Thunder Bay, Ontario, August 1982. p. 308-318.

202. Stout, J., V.L. Writght. 1971. Small mammal populations of an area in northern Idaho severely burned in 1967. Northwest Sci. 45(4): 219-226.

203. Stransky, J. J., and L. K. Halls. 1979. Effect of a winter fire on fruit yields of woody plants. J. Wildl. Manage. 43:1007-1010.

204. Tevis, L.R. 1953. Stomach contents of chipmunks and mantled squirrels in northeastern Califormia. J. Mamm. 34: 316-324.

205. Volland, L.A. 1974. Relation of pocket gophers to plant communities in the pine region of central oregon. In Wildlife and forest management in the pacific northwest. p. 149-166. 1973 Symp. Ore. State Unive, Corvalis.

206. White, M. A., and J. L. Vankat. 1993. Middle and high elevation coniferous forest communities of the north rim region of Grand Canyon National Park, Arizona. Vegetation 109:161-174.

207. Wood, G. W. 1988. Effects of prescribed fire on deer forage and nutrients. Wildl. Soc. Bull. 16:180-186.

208. Yensen, E., D. L. Quinney, K. Johnson, K. Timmerman, and K. Steenhof. 1992. Fire, vegetation changes, and population fluctuations of Townsend's ground squirrels. Amer. Midland Naturalist 128:299-312.

ADDITIONAL LITERATURE AND COMMUNICATIONS

Covington, W.C. and Margaret Moore. 1994. Postsettlement changes in natural fire regimes and forest structure: Ecological restoration of old-growth ponderosa pine forests. The Jour. of Sustainable Forestry, 2(153 -181).

209. Taylor, Cathy. 1995. Communication with Peter Paton (1987). USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Arcata, CA.

Taylor, Cathy. 1995. Chipmunk study in northern California. Unpublished data from 1987. USDA Forest Service, Coconino National Forest, Happy Jack, AZ.

USDA 1994. Fire effect guide. National Wildfire Coordinating Group. PMS 481, NFES 2394. National Interagency Fire Center, Boise, ID.

210. White, P.J. and Robert A. Garrott. 1993. Why do elk eat burned bark. Yellowstone Science. Summer.

APPENDIX A

Effects of Fire on Amphibians and Reptiles.

1. Green rat snake (Elaphe triaspis).

   This species has been observed to make denning sites in the use burned out bases and loose bark on lightning-killed snags. R-4.

2. Western diamondback rattlesnake (Crotalus atrox).

   Southern diamondback rattlesnakes commonly were found on burned sites. Burrows are often located in burned stumps probably because of the warmer temperatures on burned sites. R-81.

APPENDIX B

Effects of Fire on Birds.

1. Acorn Woodpecker (Melanerpes formicivorus).

   May increase habitat use after fire in ponderosa pine in response to increased insect populations. R-99.

2. American crow (Corvus brachyrhynchos).

   May be attracted to smoke, flames, black and greening burns. R-81.

3. American kestral (Falco sparverius).

   May be attracted to fire and recent burns; increases habitat use after fire. This species is negatively affected by canopy closure. R-19, 54, 82, 88, 103, 139.

4. American robin (Turdus migratorius).

   May be attracted to smoke, fire, and very recent burns. This species is a ground feeder/canopy nester that benefits when fire creates increased edge habitat. Often is abundant in early post-fire successional communities in shrub and forest types. Higher abundance in recently burned mixed-conifer forest than unburned areas. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-19, 66, 81, 103, 108, 124, 139, 147, 201.

5. American tree sparrow (Spizella arborea).

   May be attracted to black and greening burns. R-81.

6. Ash-throated flycatcher (Myiarchus cinerascens).

   Reportedly more abundant in forests with history of fire suppression in southern Arizona. R-103.

7. Bewick's wren (Thyromanes bewickii).

   More abundant on unburned chaparral. Closely associated with shrubby habitat. R-88, 164.

8. Black and white warbler.

   Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

9. Black-billed magpie (Pica pica).

May be attracted to black and greening burns. R-81.

10. Black-capped chickadee (Parus atrogularis).

May be attracted to fires; observed feeding on insects near flames. Primary cavity nester that depends on mature aspen for reproductive habitat. Prefers unburned lodgepole pine forest to post-fire successional habitat. R-59, 81, 124.

11. Black-chinned sparrow (Spizella atrogularis).

More common on burned chaparral. R-164.

12. Black-headed grosbeak (Pheucticus melanocephalus).

Use of cut-over Douglar-fir forests increased because of habitat diversity. This suggests fire effects may be beneficial. R-62.

13. Black-throated blue warbler.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

14. Black-throated gray warbler (Dendroica nigrescens).

Reportedly more common in southern Arizona forests with a history of fire suppression. This suggests that fire effects may be detrimental. R-103.

15. Black vulture (Coragyps atratus).

May be attracted to very recent burns. R-4, 81.

16. Blue grosbeak (Guiraca caerulea).

May be attracted to black and greening burns. R-81.

17. Blue-gray gnatcatcher (Polioptila caerulea).

Reportedly more abundant in forests with history of fire suppression in southern Arizona. This suggests that fire effects may be detrimental. R-103.

18. Blue grouse (Dendragapus obscurus).

Low population densities in mature spruce/fir forests increased after fire. Edge habitat is important to this species, which requires brush and tree thickets associated with open forage areas. This species is more adapted to xeric conditions than other grouse. Burned areas are preferred brood range. Benefits from increased forb and insect availability after fire. R-11, 25, 100, 104, 120.

19. Blue jay (Cyanocitta cristata).

May be attracted to black and greening burns. R-81.

20. Blue-winged teal (Anas discors).

Benefits from fire opened wetlands. R-156.

21. Brewer's sparrow (Spizella breweri).

Numbers decreases in sagebrush/grasslands when shrub cover was reduced by fire or other means. Increased in conifer types after fires. R-12, 19, 59, 127.

22. Brown creeper (Certhia americana).

Fire and clearcutting reduced habitat use. This species prefers mature forest. R-5, 19, 54, 66, 99.

23. Brown thrasher (Toxostoma rufum).

May be attracted to black and greening burns. R-81.

24. Brown towhee (Pipilo fuscus).

Habitat use in chaparral decreased after fire. This species is associated with shrubby cover. R-88, 103, 118, 164.

25. Brown-headed cowbird (Molothrus ater).

Opportunistic species apparently neither positively nor negatively affected by fire. May be attracted to black and greening burns. R-19, 81, 99.

26. Burrowing owl (Athene cuncicularia).

Populations of this species on grasslands have been reported to decline with increases in litter cover. This suggests that use of fire to eliminate litter may be benficial. R-81.

27. Bushtit (Psaltriparus minimus).

Habitat use decreased after fire due to loss of dense brush cover. R-29, 164.

28. Canada goose (Branta canadensis).

Observed to gather on greening burns. R-81.

29. Canada warbler.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

30. Cassin's finch (Carpodacus cassinii).

This ground brush feeder increased foraging use of conifer habitat after fire. Benefits from opened areas but requires live trees for nesting cover. R-19, 147.

31. Cassin's kingbird (Tyrannus vociferans).

More common in southern Arizona forests that have been affected by frequent fire than in similar habitat subject to suppression for 60 years. R-103.

32. Cedar waxwing (Bombycilla cendrorum).

May be attracted to greening burns. R-81.

33. Chestnut-collared longspur (Calcarius ornatus).

This species is fairly specialized in terms of cover requirements, and is found primarily in grass/shrub areas in openings 64 m or more from cover. R-118.

34. Chestnut-sided warbler.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

35. Chipping sparrow (Spizella passerina).

This species is tolerant of habitat disturbance. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may be attracted to recently burned areas. R-18, 19, 81, 99, 103, 118, 201.

36. Clark's nutcracker (Nucifraga columbiana).

Highly mobile species attracted to greening burns and open areas. Present in conifer forests until canopy closure. R-18, 39, 147.

37. Cliff swallow (Hirundo pyrrhonota).

Vagrant species, attracted to burned areas in conifer forests. R-19.

38. Common ground-dove (Columbia passerina).

May be attracted to black and greening burns. R-81.

39. Common flicker.

Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-201.

40. Common nighthawk (Chordeiles minor).

More common in southern Arizona forests which have been affected by frequent fires. Vagrant species on mixed conifer sites before and after burns. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas R-19, 103, 201.

41. Common poorwill (Phalaenoptilus nuttallii).

Vagrant species in conifer forests attracted to burned areas. R-19.

42. Common raven (Corvus corax).

Chaparral use increased after fire, and decreased with increasing canopy cover. R-88.

43. Common snipe (Gallinago gallinago).

May be attracted to black and greening burns. R-81.

44. Common yellowthroat.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

45. Cooper's hawk (Accipiter cooperii).

May be attracted to fire or smoke. Observed hunting at fires and on black and greening burns. Use of burned areas decreased with increasing canopy cover. R-81, 88.

46. Coues' flycatcher (Contopus pertinax).

Habitat use in selectively cut mixed-conifer forest was greater than uncut mixed-conifer. Preferred open, parklike stands. R-54.

47. Curve-billed thrasher (Toxostoma curvirostre).

Reported more common in southern Arizona forests which have been affected by fire. R-103.

48. Dark-eyed junco (Junco hyemalis).

This ground/brush feeder is highly tolerant of habitat alterations. May increase habitat use immediately after fire and logging. R-52, 99, 124, 144.

49. Downy woodpecker (Picoides pubescens).

This extremely mobile species may be attracted to recent burns because of increased insect availability. R-4, 84, 201.

50. Eastern bluebird (Sialia sialis).

Reported to be more common in pine-oak forests affected by frequent natural fires. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-103, 201.

51. Eastern kingbird (Tyrannus tyrannus).

May be attracted to smoke and fire; hunts insects in front of a head fire. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-81, 201.

52. Eastern meadowlark (Sturnella magna).

May be attracted to black and greening burns. Fires that destroy all shrub cover may be detrimental. R-18, 81.

53. Eastern phoebe.

Numbers declined after burn in mixed-conifer forest. R-201.

54. Elf owl (Micrathene whitneyi).

More common in southern Arizona forests that have been subject to fire suppression. R-103.

55. European starling (Sturnus vulgaris).

May be attracted to blackened burned areas. R-81.

56. Evening grosbeak (Hesperiphona vespertina).

Habitat use by this tree foraging/seed eater decreases after fire in conifer forests. Higher abundance in recently burned mixed conifer forest than unburned area. May be due to a good supply of seed available in burn. R-19, 62, 81, 201.

57. Fox sparrow (Passerella iliaca).

May be attracted to black and greening burns. Use of conifer forests increases after fire. R-19, 81.

58. Gadwall (Anas strepera).

Benefits from fire-opened wetlands. R-156.

59. Gambel's quail (Callipepla gambelii).

May benefit from spot burning in chaparral due to increased forb and insect availability. R-24, 81.

60. Golden-crowned kinglet (Regulus satrapa).

This tree=foliage-searcher forages in dense spruce/fir forests and is more common in unburned areas. Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-19, 59, 147, 201.

61. Grace's warbler (Dendroica graciae).

Habitat use decreased in ponderosa pine forests after tree removal. This suggests that large, tree removing fires may be detrimental. R-144.

62. Grasshopper sparrow (Ammodramus savannarum).

Fire in grass-shrub habitat may be detrimental to this species. Some shrubs are required for nesting and perching. R-19, 118.

63. Gray jay (Perisoreus canadensis).

Ubiquitous on various successional stages of spruce/fir forest following fire. Prefers unburned lodgpole forest to post-fire successional stages. R-124, 147.

64. Great blue heron (Ardea herodias).

Observed on recent black and greening burns. R-81.

65. Great horned owl (Bubo virginianus).

More common in unburned forest. It may be attracted to smoke and fire because of increased prey vulnerability. R-19, 81.

66. Greater roadrunner (Geococcyx californianus).

More common in southern Arizona woodlands that have been subject to natural fire frequencies than in areas where fire has been suppressed. R-103.

67. Great-tailed grackle (Quiscalus mexicanus).

May be attracted to black and greening burns. R-81.

68. Green-tailed towhee (Pipilo chlorurus).

Use of forest openings after fire increased in ponderosa pine and mixed conifer. R-19, 99.

69. Hairy woodpecker (Picoides villosus).

Insects associated with fire-killed trees attract this species. Abundance is higher in recently burned mixed conifer forests than in unburned areas. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may be attracted to recently burned areas. R-19, 84, 99, 146, 147, 201.

70. Hammond's flycatcher (Empidonax hammondii).

More use of mature uncut forests. This suggests that fire effects may be detrimental to this species. R-62.

71. Hermit thrush (Catharus gattatus).

This ground-foraging species prefers dense spruce/fir forests. Less common after fire and timber harvesting. Higher abundance in recently burned mixed-conifer forest than in unburned areas. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. R-19, 54, 66, 124, 201.

72. Hermit warbler (Dendroica occidentalis).

Habitat use decreased after timber harvest in conifer forests. Fire effects may also be detrimental. R-62.

73. Horned lark (Eremophila alpestris).

May be attracted to greening burns. R-81.

74. House wren (Troglodytes aedon).

This ground/brush-foraging species increased after fire and timber harvesting in conifer forests. Cavity nester in mature aspen. Small increase in numbers in recently burned mixed-conifer forest. R-19, 54, 59, 81, 201.

75. Killdeer (Charadrius vociferus).

May be attracted by smoke and fire. Feeds on fleeing insects. Has been observed on black and greening burns. R-81.

76. Lark bunting (Calamospiza melanocorys).

May be attracted to black and greening burns. R-81.

77. Lark sparrow (Chondestes grammacus).

Increased habitat use after chaparral fire. Benefits from reduction but not complete removal of shrubs. Benefits from litter removal in grasslands. R-88, 122, 164.

78. Lazuli bunting (Passerina amoena).

Use of chaparral habitat increased after fire. In conifer forest, prefered to nest on burned areas. R-19, 81, 164.

79. Lesser prarie-chicken (Tympanuchus pallidicinctus).

This grassland species is declining in the Southwest because of decreased grassland habitat. Fire suppression is a factor in the decline of grasslands. R-24.

80. Loggerhead shrike (Lanius ludovicianus).

May be attracted to smoke, flames, black and greening burns. R-81.

81. MacGillivray's warbler (Oporornis tolmiei).

Vagrant species observed in both burned and unburned conifer forest. R-19.

82. Magnolia warbler.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

83. Mallard (Anas platyrhynchos).

Benefits from fire-opened wetlands. R-156.

84. Montezuma quail (Cyrtonyx montezumae).

This grassland species is declining in the Southwest due to the loss of grass-forb habitat in grazed areas. May benefit from spot burning which decreases shrub cover. R-24.

85. Mountain bluebird (Sialia currucoides).

Common nesting species on recent burns in conifer types. Highest population densities recorded at 5-29 years post-fire. Often used fire-killed snags as nest sites. R-19, 66, 99, 124, 146, 147.

86. Mountain chickadee (Parus gambelii).

Habitat use decreased after fire in conifer types. Some nesting use of burned snags reported in mixed conifer, when live trees are available nearby. R-19, 66, 99, 147.

87. Mourning dove (Zenaida macroura).

May be attracted to recent burns. Habitat use and nesting success increased in conifer, grasslands, and chaparral vegetation types after fires. R-18, 19, 81, 88, 99, 137, 139, 164.

88. Nashville warbler.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

89. Northern bobwhite (Colinus virginianus).

Attracted to black and greening burns. This species is most productive in grass-forb habitat. Requires scattered brush for cover, but decreases in shrub dominated stands. R-24, 44, 76, 81, 122, 149, 154, 165.

90. Northern cardinal (Cardinalis cardinalis).

May be attracted to black and greening burns. R-81

91. Northern flicker (Colaptes auratus).

Highly tolerant and mobile species. Increased habitat use after fire in response to increased insect populations. R-35, 99, 124, 144.

92. Northern goshawk (Accipiter gentilis).

May increase hunting on recent burns in conifer forests due to increased vulnerability of prey species. R-19.

93. Northern harrier (Circus cyaneus).

May be attracted to smoke and flames. Observed hunting on black and greeening burns. R-81.

94. Northern mockingbird (Mimus polyglottos).

May be attracted to black and greening burns. R-81.

95. Northern pintail (Anas acuta).

Benefits from fire-opened wetlands. R-156.

96. Northern rough-winged swallow (Stelgidopteryx serripennis).

Hunts ahead of flames. May be attracted to fire, smoke and blackened burned areas. R-81.

97. Olive-sided flycatcher (Nuttallornis borealis).

Habitat use increased after fire and timber harvest in conifer forests. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-19, 59, 62, 99, 201.

98. Orchard oriole (Icterus spurius).

May be attracted to black and greening burns. R-81.

99. Ovenbird.

Numbers declined in recently burned mixed-conifer forest. R-201.

100. Pine siskin (Carduelis pinus).

Fire and timber harvests may reduce habitat use. R-19, 62.

101. Purple finch (Carpodacus purpureus).

A tree-foraging seed eater. Fire may be detrimental. In a mixed-conifer forest, no difference in numbers between a recently burned area and an unburned area. May be due to a good supply of seed available in burn. R-62, 201.

102. Purple martin (Progne subis).

May be attracted to smoke and flames. Observed foraging on insects near headfires. More common in conifer forests after fire and logging. R-54, 81, 103, 139.

103. Pygmy nuthatch (Sitta pygmaea).

This tree gleaning species is decreased by timber harvest and tree-destroying fires. R-19, 99.

104. Red crossbill (Loxia curvirostra).

This tree-foraging seed eater confined feeding to uncut forested area when a clearcut area was available. Fire may be detrimental. R-62.

105. Red-breasted nuthatch (Sitta canadensis).

Decreased as a breeding species by timber removal and fire in conifers. May be attracted to burns. As foraging species, concentrates on dead foliage and live standing trees. R-19, 62, 66, 147.

106. Red-eyed vireo.

Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-201.

107. Red-faced warbler (Cardellina rubrifrons).

Habitat use decreased after timber harvest in conifer forests. Fire effects may also be detrimental. R-54.

108. Red-tailed hawk (Buteo jamaicensis).

May be attracted to smoke and flames. This species has been observed hunting on black and greening burns. Increased habitat use is reported in chaparral and conifer forests following fire and timber harvests in response to increased availability of rodent prey species. R-4, 19, 54, 62, 81, 88, 139.

109. Red-winged blackbird (Agelaius phoeniceus).

Attracted to black and greening burns. R-81.

110. Ruby-crowned kinglet (Regulus calendula).

Fire and timber harvest in spruce/fir forests are detrimental to this species. No change in abundance before and after burn in mixed-conifer forest. R-54, 147, 201.

112. Ruffed grouse.

Numbers declined in recently burned mixed-conifer forest. R-201.

113. Rufous-crowned sparrow (Aimophila carpalis).

In a grass/shrub community, this species used habitat space up to 4 m from cover. R-118.

114. Rufous-sided towhee (Pipilo erythrophthalmus).

Mixed response to fire reported. This species is closely associated with shrubby habitat. May be attracted to recent burns. Spot burning in chaparral habitat that creates diversity may benefit species. Total shrub removal is detrimental. R-81, 103, 108, 164.

115. Sandhill crane (Grus canadensis).

Regrowth of grasses, reduced litter, and decreased shrub cover in grasslands following fire is beneficial. R-78, 83, 171.

116. Savannah sparrow (Passerculus sandwichensis).

May be attracted to black and greening burns. Fire may be beneficial by increasing perennial grasses and forbs in shrub-invaded areas. Reported to avoid recently burned grasslands but returns after grasses have recovered. R-24, 42, 81, 118.

117. Scaled quail (Callipepla squamata).

May be attracted to recent burns. This is primarily a grassland species which has adapted to use of shrub-invaded habitat. May benefit from spot burning in dense shrub areas. R-24, 44, 81.

118. Scarlet tanager.

Numbers declined in recently burned mixed-conifer forest. R-201.

119. Scott's oriole (Icterus parisorum).

More common in southern Arizona forests that have been subject to fire suppression. Fire effects may be detrimental. R-103.

120. Scrub jay (Aphelocoma coerulescens).

More abundant on unburned chaparral. Habitat use decreased after fire. R-164.

121. Sharp-shinned hawk (Accipiter striatus).

Use of habitat increased following fire and timber harvesting in conifer forests and chaparral due to increased availability of small birds. R-62, 88.

122. Slate-colored junco.

In a mixed-conifer forest, numbers increased in burned forest versus an unburned forest. May be due to a good supply of seed available in burn. R-201.

123. Snowy egret (Egretta thula).

May be attracted to recent greening burns. R-81.

124. Solitary vireo (Vireo solitarius).

This tree-foliage-searching insectivore is moderately tolerant of habitat alteration. Habitat use decreased after fire in conifer forest where trees were destroyed. R-19, 100, 144.

125. Song sparrow (Melospiza melodia).

May be attracted to black and greening burns. In a mixed-conifer forest, numbers increased in burned forest versus an unburned forest. May be due to a good supply of seed available in burn. R-77, 201.

126. Spotted owl (Strix occidentalis).

Old-growth spruce/fir is required for this species. Negatively affected by fire. Sometimes hunts in burned areas following fire. R-102, 209.

127. Steller's jay (Cuanocitta stelleri).

May be attracted to black and greening burns. Habitat use increases in conifer forests after fire and timber harvesting. This species appears to prefer to nest in unburned forest. R-19, 62, 81, 99.

128. Summer tanager (Piranga rubra).

May be attracted to greening burns. R-81.

129. Swainson's thrush.

Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas. R-201

130. Three-toed woodpecker (Picoides tridactylus).

Insects associated with fire-killed trees attract this species to recent burns in conifer forests. R-19, 84, 146, 147.

131. Townsend's solitaire (Myadestes townsendi).

Breeding species in conifer woodlands in burned and unburned areas. More abundant in early successional habitat than in dense tree stands. R-19, 124.

132. Tree swallow (Tachycineta bicolor).

Reported to hunt insects in smoke at fires. May be attracted to burned areas where it nests in snags and mature decadent aspen. Negatively affected by canopy closure in mature forests. Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from increased exposure after vegetation destruction and flushing effects. Some insects may even be attracted to recently burned areas (Spires 1982). R-19, 59, 81, 146, 147, 201.

133. Turkey vulture (Cathartes aura).

May be attracted to very recent burns. R-19, 81.

134. Vaux's swift (Chaetura vauxi).

Vagrant species in mixed conifer forests, attracted to burned areas. R-19.

135. Veery.

In a mixed-conifer forest, numbers decreased in the burned area compared to the unburned area. R-201.

136. Vesper sparrow (Pooecetes gramineus).

May be attracted to black and greening burns. Increased habitat use in shrublands when shrub cover is decreased. R-12, 81, 99, 118.

137. Violet-green swallow (Tachycineta thalassina).

More common on burned or selectively cut areas in conifer forest. R-54, 103.

138. Virginia's warbler (Vermivora virginiae).

Habitat use decreased in ponderosa pine forest after fires that removed trees. R-99.

139. Western bluebird (Sialia mexicana).

Increased population densities reported for very recent burns and selectively cut areas in conifer forest. Demonstrated a tolerance for habitat alteration. R-54, 99, 103, 144.

140. Western flycatcher (Empidonax difficilis).

Prefered uncut forest to selectively cut conifer forest. Fire may be detrimental. R-54.

141. Western kingbird (Tyrannus verticalis).

Use of chaparral habitat increased with increased grass cover after fire. R-88.

142. Western meadowlark (Sturnella neglecta).

May be attracted to black and greening burns. Benefits from increased forb and grass component after chaparral fires. R-81, 88.

143. Western screech-owl (Otus kennicottii).

More common in southern Arizona with unrestricted fire histories. Fire effects may be beneficial. R-103.

144. Western tanager (Piranga ludoviciana).

This species may be negatively affected by fire in spruce/fir forests. May forage on recent burns in standing foliate trees. Has used unburned and burned forests, and cutovers where some trees have remained. R-19, 62, 99, 147.

145. Western wood-pewee (Contopus sordidulus).

May be attracted to fires and recent burns by increased insect populations. R-19, 62, 81, 99.

146. Whip-poor-will.

Higher abundance in recently burned mixed conifer forest than unburned area. This may be due to a good supply of insects resulting from flushing effects and increased exposure after vegetation destruction. Some insects may even be attracted to recently burned areas. R-201.

147. White-breasted nuthatch (Sitta carolinensis).

This highly tolerant timber-gleaning species adjusted well to habitat alterations. Habitat use decreased after timber loss to fire. R-19, 99, 144.

148. White-crowned sparrow (Zonotrichia leucophrys).

Depends on shrub cover, and may decrease habitat use on some burned areas. Accumulated in large groups to feed in open burns and cutovers. R-62, 118, 147.

149. White-throated sparrow (Zonotricha albicollis).

May be attracted to black and greening burns. Closely associated with heavy understory growth in pine communities. May decrease after ground fires in this community type. In a mixed-conifer forest, numbers increased after area burned. May be due to a good supply of seeds available in the burn. R-81, 108, 201.

150. Wild turkey (Meleagris gallopavo).

Increased habitat use after fire. Benefits from increased availability of forbs and insects on burns. R-4, 20, 52, 81, 129, 139.

151. Williamson's sapsucker (Sphyrapicus thyroideus).

Fire may increase the success of this species in conifer forests. R-19, 66.

152. Winter wren (Troglodytes troglodytes).

Increased habitat use on recent conifer cutover because this species uses slash piles. Numbers remained the same in unburned and burned areas of mixed-conifer forest. R-62, 201.

153. Wood thrush.

In a mixed-conifer forest, numbers decreased in the burned area compared to the unburned area. R-201.

154. Yellow-bellied sapsucker (Sphyrapicus varius).

May increase habitat use after fire and logging in conifer forests. R-19, 54.

155. Yellow-rumped warbler (Dendroica coronata).

This tree-foliage-searching species may increase ground foraging on burns. More abundant in unburned spruce/fir forests. Abundant on both burned and unburned conifer forest. Numbers declined after burn in mixed-conifer forest. This may be due to destruction of herbivorous insects by the fire. R-66, 99, 124, 147, 201.

137. Yellow warbler (Dendroica petechia).

Vagrant species in mixed-conifer forests. Decreased habitat use after fire in mixed-conifer forests. More common in southern Arizona woodlands that have been subject to natural fire frequencies than in similar areas where fire has been suppressed. R-19.

APPENDIX C

Effects of Fire on Mammals.

1. Arizona cotton rat (Sigmodon arizonae).

   May be attracted to black and greening burns. This species is reported to be very effective at detecting fire and avoiding injury. Southern Arizona grassland fire in February and April decreased grass cover and cotton rats for a short time. R-18, 81.

2. Arizona pocket mouse (Perognathus amplus).

   Habitat use decreased in Upper Sonoran Desert after fire due to decreased shrub cover. The ingestion of green vegetation in spring is closely associated with reproductive success. R-105, 121.

3. Badger (Taxidea taxus).

   May increase habitat use in response to fire-enhanced rodent populations. R-59, 151.

4. Bailey's pocket mouse (Perognathus baileyi).

   Upper Sonoran Desert population decreased after fire at one site due to decrease in shrub cover. R-105.

5. Beaver (Castor canadensis).

   This species is dependent on early successional plant species, such as aspen and willows, along high-elevation streams. Populations declined in 70-100 year-old post-fire communities because of their own activities. R-59, 69, 125.

6. Black bear (Ursus americanus).

   Burns and selectively cut areas in boreal forest are used heavily during the 2-20 year post-fire, post-logging period when berry-producing plants are abundant. R-40, 49, 69, 87, 111, 125.

7. Bobcat (Felis rufus).

   Habitat use after fire may increase in response to increased availability of prey. R-59.

8. Buffalo (Bison bison).

   There is some evidence that historic buffalo herds of the Great Plains were attracted to recent burns. R-78.

9. Cactus mouse (Peromyscus eremicus).

Population decreased after fire at one Upper Sonoran Desert location due to a decrease in shrub cover. Abundance of green vegetation in spring and winter is positively correlated with reproductive success. R-23, 105.

10. Chipmunk (Eutamias spp.).

Fire may improve chipmunk habitat by creating openings, if these openings contain logging slash or rock outcrops. Immediately following burn, chipmunk presence was reduced by 30 percent in conifer habitat. There may be an increase in chipmunk population when cover and seed and fruit-producing plants are re-established. R-181, 185, 187, 204.

11. Coyote (Canis latrans).

This species may increase habitat use after fire in response to increased availability of prey. Post fire habitat use by deer increased in chaparral. As canopy cover decreased, habitat use decreased. R-49, 59, 164.

12. Deer mouse (Peromyscus maniculatus).

In shrub and forest types, this species generally increased immediately after fire, often two or three times more than preburn levels. Deer mice usually were the most abundant small mammal in severely disturbed areas. Their success is partially due to their preference for seeds of grasses and herbs and insects. The deer mouse is closely associated with grass and forb cover. R-8, 9, 36, 42, 69, 88, 99, 124, 149, 163, 183, 184, 191.

13. Eastern cottontail (Sylvilagus floridanus).

May be attracted to black and greening burns. R-81.

14. Elk (Cervus elaphus).

Habitat use by elk during the 1-15 year post-fire period in a conifer forest was nearly three times that in a similar unburned forest. Burning increased abundance and nutritional quality of browse species in clearings. Clearings of 0.5 to 3.5 ha were preferred; however, use was very limited when distance to cover was greater than 0.5 km. Spring and summer grasses that increase with fall burns are preferred by elk over browse and forbs. Extensive brush fields favor deer over elk. Aspen is an important food source for elk and burning temporarily decreases, use but may eventually increase vigor and density of aspen stands. To ensure presence of aspen in coniferous forest, burning or cutting is recommended at frequencies greater than once in 200 years. R-7, 44, 52, 59, 82, 86, 90, 91, 92, 99, 104, 111, 115, 124, 133, 134, 210.

15. Golden-mantled ground squirrel (Spermophilus lateralis).

Summer habitat use decreased for 3 years in ponderosa pine forest following fire. At 7 years, post-fire population was 2.5 times greater than pre-burn levels. Fire and other disturbances that remove the forest canopy create open areas that ground squirrels prefer. Burrow systems provide protection from predators. R-99, 181.

16. Gray wolf (Canis lupus).

Habitat use by this species may increase following fire in response to increased small mammal and deer populations. R-59, 69.

17. Gray-collared chipmunk (Eutamias cinereicollis).

Population declined after fires that remove trees because Eutamias spp is dependent on live trees in ponderosa pine forests. R-99.

18. Marten (Martes americana).

Small fires may be beneficial to the marten by increasing voles and other small mammals and by decreasing fuel loads that may prevent large fires. Martens did not forage in openings greater than 100 m wide. Openings are avoided in winter but are used in fall when fruits, insects and ground squirrels are abundant. Large fires of high intensity that destroy standing trees are detrimental to the marten. R-80, 125.

19. Meadow vole (Microtus pennsylvanicus).

Predicted to increase in riparian habitat with removal or thinning of deciduous trees and increasing forb cover. This may indicate a similar reaction to post-fire habitat. R-56.

20. Merriam's kangaroo rat (Dipodomys merriami).

This species has shown a mixed response to fire in the semi-desert and desert types. Favored by increased and diversified forb and grass cover. R-23, 30, 105, 121.

21. Mountain sheep (Ovis canadensis).

Attracted to new vegetation growth on burns. Responds favorably to diversification of forb and grass cover. May benefit from early snow melt on burned areas. R-59, 82.

22. Mule deer and white-tailed deer (Odocoileus hemionus and O. virginianus).

Increased habitat use is reported for deer after fire in chaparral, forest lands, sagebrush, and Chihuahuan desert areas. Deer may have extended their distribution in grassland areas where shrub species have invaded as a result of fire suppression. Low-intensity controlled fires and wildfires that create small openings of 0.25 to 0.50 ha were preferred over large wildfire areas. Large areas are not used effectively because depth of winter snow impedes movement and feeding and exposure increases the risk of predation. Mule deer tolerate and benefit from large clearings more than white-tailed deer. Whitetails are reported to be more timid and require closer access to cover. Deer will use any clearing in forest areas, but are reported to prefer burned areas over young clear cuts.

Overall deer condition may be better when deer use burned habitat. Highly nutritious forbs and increased nutrient content of browse after fire are probably causes of improved deer vigor. Deer in dense juniper and sagebrush stands may suffer nutritional problems. Dietary intake of big sagebrush at levels greater than 20% of the animals' intake inhibits digestion. Large quantities of juniper berries in the diet contribute oils which inhibit deer rumen. Fire decreases juniper and destroys sagebrush, and is a valuable tool to diversify dense stands. Burning California chaparral resulted in decreased deer invasion of croplands and increased local hunter success. Deer have been spotted at fire sites before the ashes have thoroughly cooled. R-6, 13, 21, 33, 41, 44, 47, 52, 53, 59, 63, 68, 70, 73, 77, 78, 79, 81, 82, 86, 90, 93, 94, 96, 99, 104, 106, 107, 109, 111, 116, 123, 124, 125, 131, 132, 133, 134, 153, 154.

23. Muskrat (Ondatra zibethicus).

Controlled burning in coniferous forest and marshlands favors this species by creating edge communities and increasing aquatic plant diversity. R-117, 125.

24. Nuttall's cottontail (Sylvilagus nuttallii).

This species increased habitat use in dense pine seedling-forb stage after clearcuts. If fire created similar habitat, this species may benefit. R-38.

25. Pinyon mouse (Peromyscus truei).

May decrease in chaparral for the first years following fire. This species responded favorably to increased forb cover. R-88, 148.

26. Pocket gophers (Thomomys spp.).

Disturbance that removed the forest canopy and resulted in the development of an herbaceous vegetation food source is advantageous to pocket gophers. Burrow systems provided protection in areas lacking protective cover. R-175, 205.

27. Pronghorn (Antilocapra americana).

Sheltered wintering sites located in depressions should be retained in sagebrush during range improvement projects like controlled burning. R-28.

27. Red fox (Vulpes vulpes).

Habitat use may increase after fire with increased populations of small mammals on burns. R-59.

28. Red squirrel (Tamiasciurus hudsonicus).

This species may be eliminated after fire in conifer types if trees are removed. R-125, 145.

29. Shrew (Sorex spp.).

If ground vegetation has been removed, shrews will be temporarily eliminated and will not return until ground cover has developed. They are also associated with downed logs. R-177, 183.

30. Southern red-backed vole (Clethrionomys gapperi).

More common in unburned brush prairie savannah. Appeared to decline after fire in conifer forest. R-8, 66.

31. Thirteen-lined ground squirrel (Spermophilus tridecemlineatus).

This species responds favorably to fire in brush prairie savannah. Increased in riparian habitat with removal of deciduous trees. R-8, 56.

32. Vole (Clethrionomys spp. and Microtus spp.).

Necessities include the organic layer of the ground surface, palatable herbaceous plants and moisture. A hot fire that destroys the surface organic layer will eliminate voles. Red-backed voles disappeared after burning in a pine habitat in Co. Microtines with specific niche requirements may not re-establish populations on burned areas for 5-10 years post-burn, maybe longer. Other vole species, mostly the long-tailed vole, appeared in catches for the first time following a burn. R-183, 187, 202.

33. Western harvest mouse (Reithrodontomys megalotis).

Predicted to increase in habitat where deciduous trees are removed or thinned. Reproductive success is positively correlated with forb cover, therefore may increase after fire. R-56.

34. White-footed mouse (Peromyscus leucopus).

This species is predicted to decline after fire destroys deciduous trees and shrubs. Favors shrubby habitat and woody plant debris. R-8, 56.

35. White-tailed antelope ground squirrel (Ammospermophilus leucurus).

Population at one Upper Sonoran Desert location decreased the first year following fire, but later increased habitat use with increased forb and grass cover. Abundance of green vegetation in spring and winter is positively correlated with reproductive success. R-23, 105.

36. White-tailed deer (see Mule deer)

37. White-throated woodrat (Neotoma albigula).

Population at one Upper Sonoran Desert site decreased after fire possibly due to decreased cover and loss of cacti. R-105.

APPENDIX D

Plant-Fire Response Classification.

Fire-Resistant Species

Trees with perennating buds well above ground; life spans 300 to 1,000 years; thick bark or trunk covered with insulating layer of poorly flammable material; DBH usually >50 cm; leaves and branches conspicuously absent on lower half of plant; fire scars may be conspicuous.

Fire-Intolerant Decreaser

Herbs, shrubs or trees; location of perennating buds various; life spans from 1 to 1,000 years; fire resistant covering not apparent; if diameter of stem is >50 cm then leaves and branches present to plant base; fire scars uncommon.

Herbs, shrubs and trees; perennating buds at or above soil line, poorly if at all protected; generally slow growth potentials; non-sprouting, or with very finely divided morphologies; seeds not conspicuously mobile; seeds of short viability; seed dormancy mechanisms uncommon.

Fire-Tolerant Species

Herbs, shrubs and trees; perennating bud generally protected at or below soil line, or as seed in annual species; moderate to very rapid growth potentials; seed production often copious; seeds long-lived, highly mobile and/or with dormancy characteristics.

Shrubs, perennial herbs and small trees; perennating bud at soil line or below; resprouts after top kill; seeds not conspicuously mobile.

Fire-Intolerant Increaser

Shrubs and herbs; perennating buds above soil line or plant is an annual; spectacular regrowth and site invasion common after fire; reproduction predominately from seed; canopy and/or soil stored seed banks; dormancies active and are apparently responsible for presence of seed bank; seeds long-lived and produced in large quantities each year.

APPENDIX E

Forest Service Fire Size Classification

Class	Acres
A	<.25
B	.25 - 9.9
C	10 - 99
D	100 - 299
E	300 - 999
F	1000 - 5000
G	>5000

APPENDIX F

Justifications for Management Matrix Ratings

Mobility/Fire	Reasoning
L/L:	Little loss of food and cover. Small animals can escape to dens. Large animals can move away from fire. Probably little effect <3 years. After 3 years there is more food and cover because of an increase in nutrients. Size of burn is not a factor.
L/M:	Some small animals killed. Greater loss of food and cover. Populations will recover easily as food and cover increases. More recovery time for small animal populations as size of burn increases >class E.
L/H:	Many small animals are killed. Populations in burns >class E will take longer to re-establish as a result of a greater loss of food and cover. Effects are greatly dependent on size of burn.
M/L:	Little or no effect on animals of moderate mobility when burn is <class E. Beneficial effects occur after 3 years as food and cover get restablished.
M/M:	Some small mammals are killed but total population is little affected. After 3 years there is more food and cover because of an increase in nutrients. Large animals can use a wider range of sizes that have been burned.
M/H:	Effects are accentuated as size of burn increases >class E. Small mammal populations will recover but at a slower rate and then only when food and cover are restablished.

H/L: Little or no effect on highly mobile animals.
Positive effects >3 years because of nutrient increase in food plants.

H/M: Some loss of young animals could occur especially if burn is large.

H/H: Effects are dependent on size of burn.
Young are most vulnerable.
For ungulates there can be a positive after 3 years because of an increase in plant nutrients.
